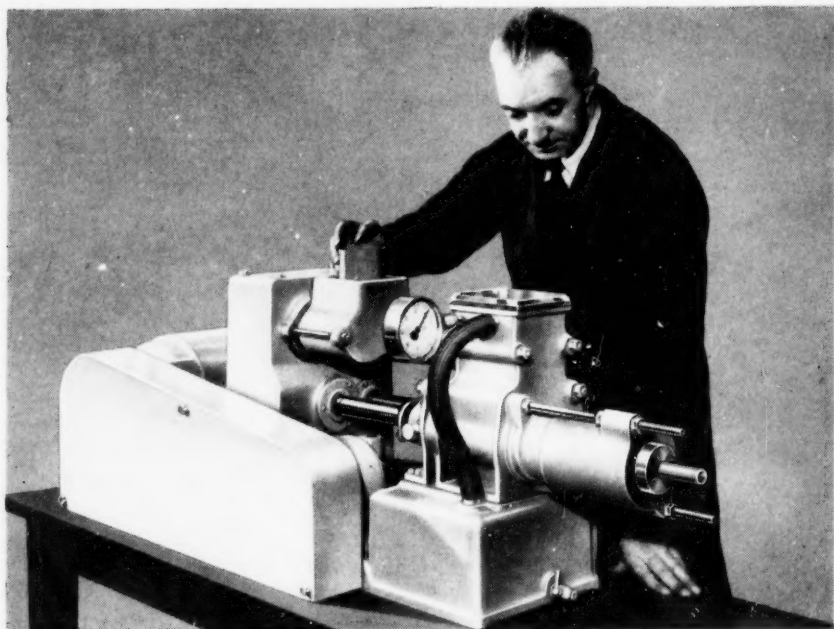


CERAMICS

FEBRUARY
1954

No. 60 Vol. V



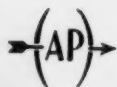
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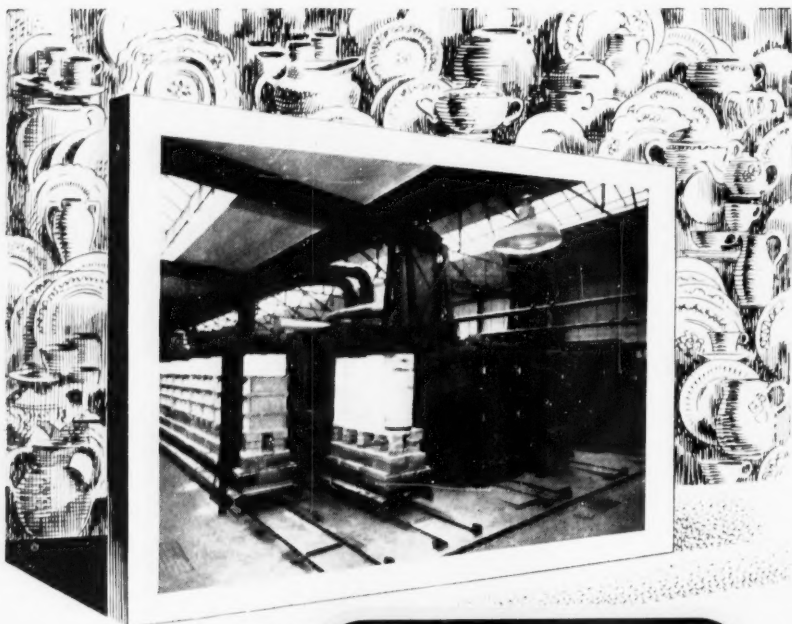
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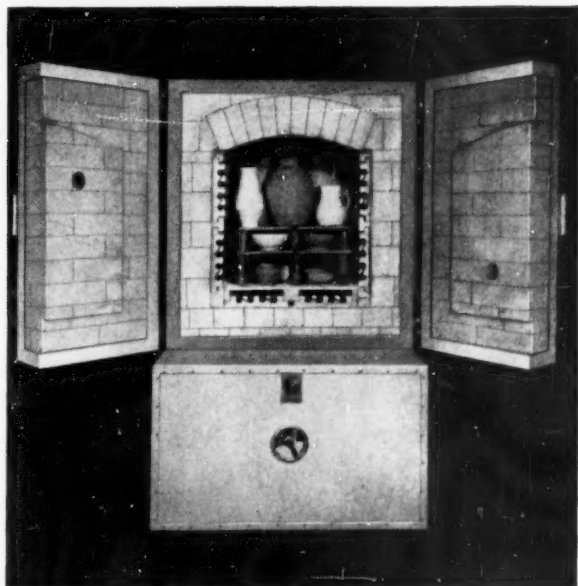


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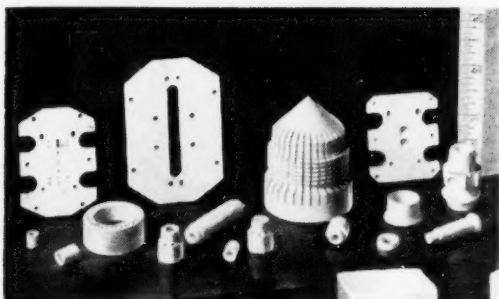
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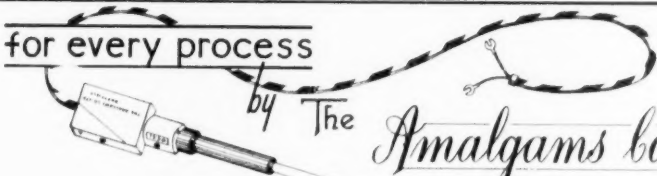
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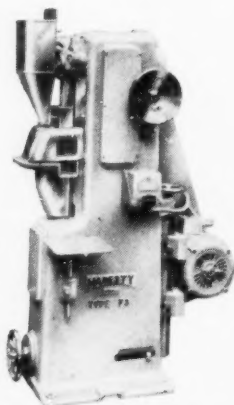
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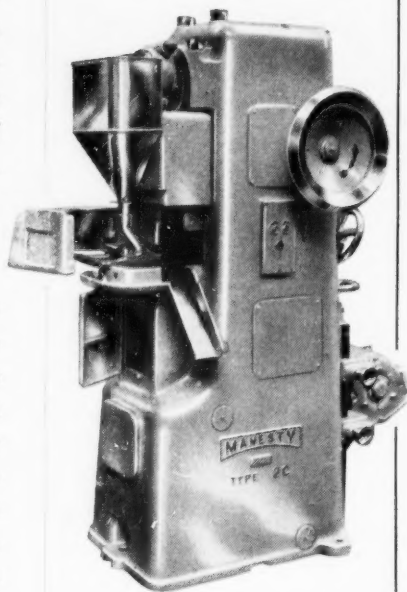
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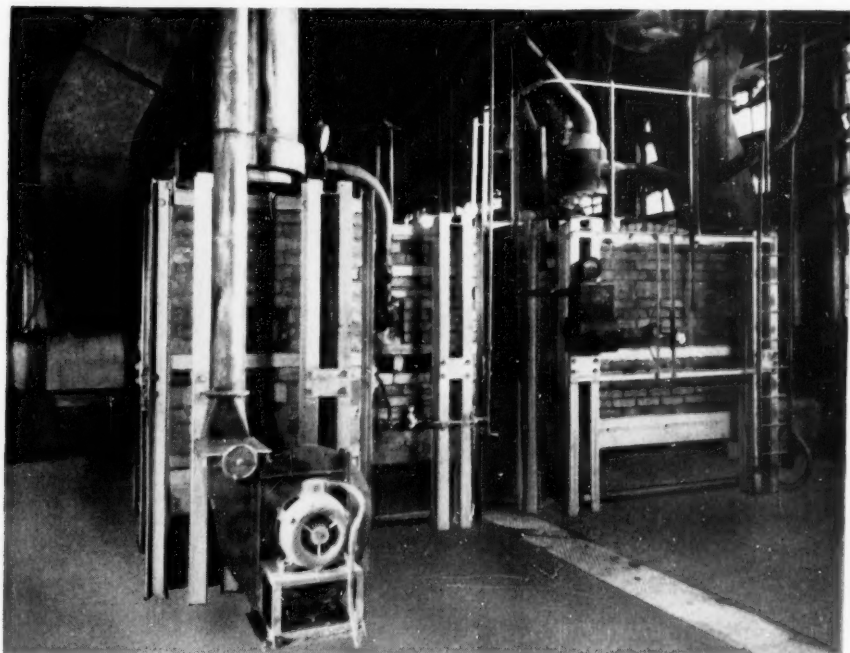
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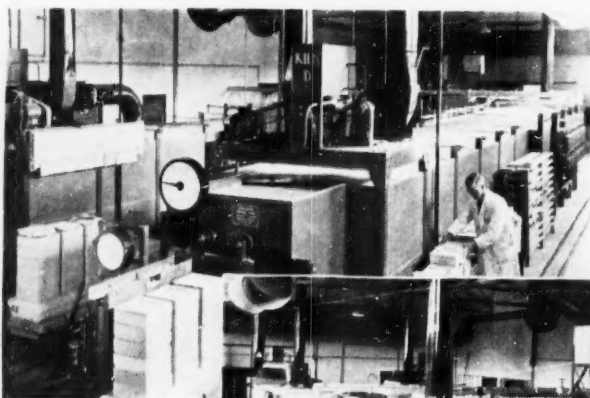
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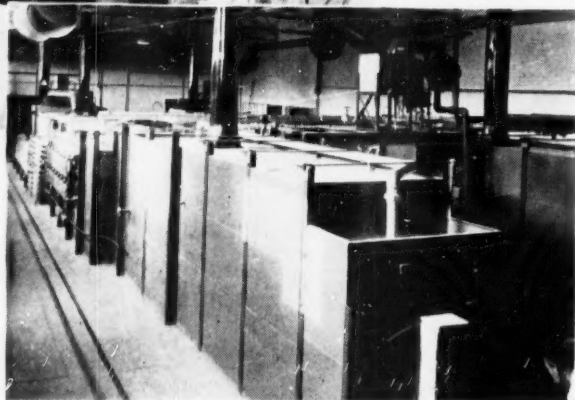
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CERAMICS

FEBRUARY 1954

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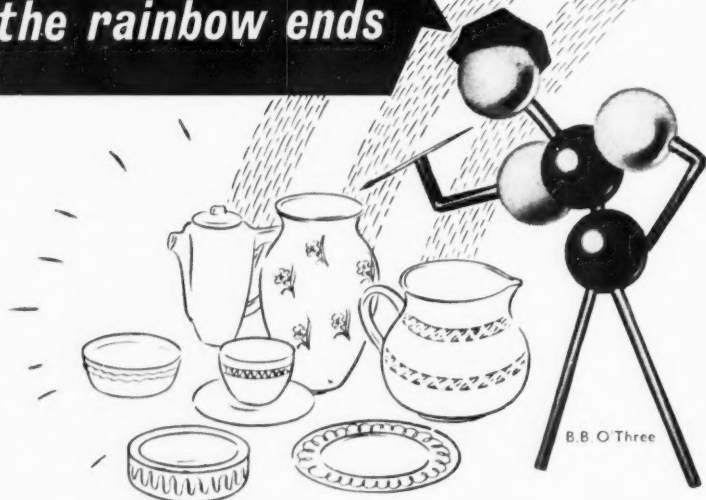
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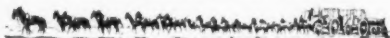
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Ceramics



VOL. V

FEBRUARY, 1954

NO. 60

A Counter-Challenge !

IN "Challenge to Britain"—the Labour Party's programme, adopted at the 1953 Margate Conference, there is support for a substantial degree of public ownership in the chemical industry. Imperial Chemical Industries Ltd. have wisely prepared a booklet for distribution to all stockholders and employees in the company, stating the case for the "defence!"

The major argument pin-pointed "the dangers of monopoly." I.C.I. admit quite freely that in many aspects they approach the monopoly, or near-monopoly stage, but wisely point out, "There are just as many, if not more, dangers inherent in statutory monopoly." There are many examples to show that new private enterprise companies do enter in competition with products which had previously been monopolised—patent protection is but for a limited period.

Against this, those industries operated under the varying Nationalisation Acts are complete and absolute monopolies—no one can make gas, electricity, or dig coal for sale. The law says No! The private monopoly is open to competition, but the statutory monopoly is not kept alive by this constant threat.

From the staff and employee viewpoint a statutory monopoly can be a virtual closed shop—if, for one reason or another an employee does "sin against" the hierarchy of a statutory monopoly he may find it necessary to sacrifice his skill and experience in his industry, for there is no alternative employment. What is more, these statutory monopolies are not subject to inquiry by the Monopolies Commission.

It has often been argued by the "Nationalisationists" that their scheme transfers industry to public control. Yet the industrial consumer of coal can negotiate merely through the Industrial Coal Consumers' Council. This meets in private without publishing its findings! Since the cost of production of both electricity and gas is largely related to the price of coal, the net result is that the public have no control whatsoever over the whole of the fuel industries—or for that matter, railway fares.

I.C.I. have a fine record of post-war capital investment—their agency factories during the war were acknowledged to be superior in many ways in terms of efficiency/cost to the "nationalised ordnance factories." Their staff relations and joint consultative machinery at all levels have been quoted as models. Admittedly the company has power, but being a public company the public is protected through the various Companies Acts, which draw a tighter rein around I.C.I. than is ever the case with say, the National Coal Board. This latter functions under an Act of its own and is more or less outside company law.

The Board of I.C.I. are to be congratulated in framing their case, for even those who once believed in nationalisation, seeing it in practice shake their heads in doubt. The recent Select Committee in the House of Commons reported upon the accountability of the nationalised industries to the public through Parliament—and the report more or less admitted that this problem had not been solved!

Zircon and Zirconia

Versatile Materials for the Ceramic and Allied Industries

by W. L. GERMAN, M.Sc., Ph.D. (London), F.R.I.C.

THE raw material for zirconia ZrO_2 is zircon, $ZrSiO_4$, which occurs as zircon sand on the beaches of Australia, Florida and India. This is the cheapest source of zirconium compounds. It contains about 65 per cent. of zirconia (ZrO_2). Another more expensive source is the mineral baddeleyite which is found in Brazil, and contains over 80 per cent. ZrO_2 .

Most of the zircon and zirconia marketed in this country is derived from zircon sand. In the natural state this is frequently associated with rutile and ilmenite and other minerals, but by means of special ore purifying methods involving flotation and magnetic and electrostatic separation a sample of zirconia now available on the market which can be sold to a guaranteed analysis. Granular Zircosil (Associated Lead Manufacturers Ltd.), for example, is sold with the following analysis:

Zirconia ZrO_2 65 per cent. minimum.
Silica SiO_2 (total) 34 per cent. maximum.

Silica SiO_2 (free) 1 per cent. maximum.

Titania TiO_2 0.35 per cent. maximum.

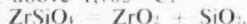
Iron oxide Fe_2O_3 0.15 per cent. maximum.

Alumina Al_2O_3 1.0 per cent. maximum.

The suppliers claim that the product is usually superior to the above guaranteed figures.

Zirconia, ZrO_2 , is made from zircon. The best methods are stated to be either by heating in an electric furnace, when the silica is volatilised, or by removing the silica by fusing with caustic soda followed by leaching out the sodium silicate with water. In either case the residue is ignited to give

zirconia.¹ Leaching the ore with sulphuric acid and igniting the sulphate has also been described.² The first method is generally used. Dissociation of zircon begins at 1,550-1,600° C. and is practically complete on prolonged heating above 1,705° C.



Commercial grades of zirconia are now available with up to 91 per cent. ZrO_2 . For Zedox T (Associated Lead Manufacturers Ltd.) the suppliers give:

Zirconia (ZrO_2) 90-91 per cent.

Silica (SiO_2) 7.8 per cent.

Alumina (Al_2O_3) 0.6 per cent. max.

Titania (TiO_2) 0.3 per cent. max.

Iron Oxide (Fe_2O_3) 0.2 per cent. max.

Lime (CaO) 1.5 per cent. max.

Soda (Na_2O) 1.2 per cent. max.

These materials are available in various gradings to suit different requirements.

Uses of Zircon and Zirconia

Zircon and zirconia are very versatile materials and their applications are continually expanding. At present they are used for:

- (1) Opacification in glazes and enamels.
- (2) Refractory materials.
- (3) Precision casting.
- (4) Abrasives for polishing glass and for sand blasting metals.
- (5) Ingredients of some ceramic colours.
- (6) Electroceramics.

Electroceramics—Zircon Porcelain

Zircon porcelains are used in high-frequency ceramics, and have the advantage of a wider firing range than some other types. This helps to keep down losses in manufacture. The following formulae are quoted by E. C. Bloor.^{3,4}

G.S. zircon	...	...	59.3	59.2	66.7	68.5
Calcium zirconium silicate	...	...	7.4	29.6	22.2	22.6
Barium zirconium silicate	...	...	7.4	—	—	—
Magnesium zirconium silicate	...	...	7.4	—	—	—
Kentucky ball clay No. 5	...	...	18.5	11.2	11.1	8.7

The bodies are made up from the milled zircon with clay and a flux, the latter being an alkaline earth zirconium silicate, but it is stated that alkaline earth carbonates, fluorides, or silicates can be used. A blend of clays may be used, but those chosen should be as low as possible in alkali oxides, iron oxide, and titania.

Analyses of the raw materials and bodies are quoted in the above reference. The body can be shaped by throwing and turning, jolleying, extrusion or casting. For plastic-making a water content of 13-17 per cent. is used. Dust pressing can be used with the aid of organic binders, but wear on the dies is heavier than with other bodies due to the hardness of zircon. Firing is done between 1,300° C. and 1,380° C. depending on the composition. Properly fired the articles are vitreous and non-porous.

The following properties are listed for zircon porcelain (E. C. Bloor loc. cit.):

- Bulk specific gravity 3.4-3.8.
- Open pores:
 - Plastic 0.0.
 - Pressed 0.0-1.0.
- Closed pores up to 10 per cent.
- True specific gravity 3.6-3.9.
- Bending strength (lb./sq. in. $\times 10^3$) (plastic made) 20-25.
- Tensile do. 12-13.
- Compressive do. 90.
- Modulus of elasticity (lb./sq. in. $\times 10^3$) 21-24.
- Coefficient of expansion $\times 10^{-6}$ (20-1,000° C.) 4.8-4.9.
- Thermal conductivity (cal./cm./cm.²/sec./°C) $\times 10^{-3}$ 11-12.
- Specific heat cal./g./°C (20-100° C.) 0.17.
- Dielectric constant 1 Mc 8.5-8.9.
- Power factor ($\times 10^{-3}$) at 20° C. 1 Mc. 10-15.
- Te value (°C.) >700.
- Dielectric strength, peak kv./mm. 50 c/s. Plastic made sample 20-25 II (Russell).

Zircon and Zirconia in Refractories

Zircon and zirconia are finding increasing use in refractory materials. Zircon has no definite melting point, since decomposition to zirconia and silica sets in. Authorities differ as to when this begins, but no sudden changes accompany the decomposition and the use of zircon refractories is not limited to this temperature since they can be used in melting platinum. D. Kirkby gives the limit of application as 1,750° C. The specific gravity of zircon is 4.6 and a grogged brick 9 in. \times 4½ in. \times 3 in. weighs about 14.5 lb.

The expansion is relatively low, and is regular. Values for commercial zircon refractories vary from 4.5×10^{-6} for the temperature range from 20-1,500° C. This low, regular expansion is a very desirable feature, making for long life in the refractory.

Applications in Chemical Industry

Chemically it behaves as an acid refractory at high temperatures, and is resistant to molten metal except under strong oxidising conditions, and also to borosilicate glasses, metaphosphates, salt, sodium sulphate, sodium chloride-zinc chloride flux, and potassium pyrosulphate. Zircon is attacked at high temperatures by soda ash, fluorides like fluor spar, cryolite and sodium fluoride, tetra sodium pyrophosphate, molten barium chloride, and lead bronzes with more than 2 per cent. of lead. In addition, all strong basic substances react with the material including metal oxides. Metals can, however, be melted in contact with zircon refractories provided the conditions are such that oxides do not form, or where they can be turned to an acid slag by adding silica. In this way these refractories are used for melting nickel and copper alloys. They also find application in induction furnaces for melting special steels and Monel metal. Molten aluminium does not wet zircon refractories and there is no risk of interaction between them. This type of material is, therefore, used for lining melting furnaces and spouts in plants fusing aluminium.

Zircon Used in Moulds for Casting Metals

The exceptional properties of zircon make it very useful in precision casting for precoats and investments. Asso-

CERAMICS

ciated Lead Manufacturers Ltd. suggest the following formulations as bases for experiment in this field. Zircosil D is a zircon flour giving less than 1 per cent. residue on a 325 mesh sieve, and Zircosil Granular is a purified zircon sand.

PRECOATS

(1) Zircosil D made up with a solution of ethyl silicate in industrial methylated spirit as a bond. This can be sprayed.

(2)					
Zircosil granular (grm.)	60	40	20	0	
Zircosil D (grm.)	40	60	80	100	
Sodium silicate solution (ccs.)	21	26	28	29	
(20 per cent. by volume solution of $\text{Na}_2\text{O}:\text{SiO}_2$ 1:3.22)					
Wetting agent (ccs.)	0.3	0.3	0.3	0.3	

(3)					
Zircosil granular (grm.)	15	25			
Zircosil D (grm.)	10	25			
Silica flour (325 mesh) (grm.)	45	50			
150 mesh	50	25			
200 mesh	—	25			

These are bonded with sodium silicate or ethyl silicate.

Investments can be made from mixtures of the above two grades of zircon with 2.3 per cent. by weight of bentonite as a bond.

When silica is used the following are recommended for trial:

Zircosil granular (grm.)	15	25
Zircosil D (grm.)	10	25
Silica sand (on 40 mesh) (grm.)	30	—
Silica flour (325 mesh) (grm.)	45	50

These are bonded with silicon ester or sodium silicate.

Zircon can be applied as a wash to cores or moulds in the green or baked state by painting or spraying. It adheres firmly to the sand giving a very smooth surface highly resistant to metal wetting or penetration. It is also available in a form suitable for making cores by addition of raw linseed oil and water. A dry test core made from Zircosil, blended linseed oil and water and baked at 200° C. for 2 hours gave test results of the order on A.F.A. apparatus:

Green compressive strength 3.0-3.5 p.s.i.

Dry compressive strength 1,000-1,200 p.s.i.

Dry permeability 35.

Other Refractory Uses

Zircon refractories are very useful for the construction of glass tanks on account of their resistance to corrosion by acidic types of glass, e.g., borosilicate glasses.

Thus mixtures of 0.10 per cent. alumina, 20.63 per cent. china clay and 37.80 per cent. zircon have been described for fusion cast-tank blocks of the zircon-mullite type.⁶ There is also the corundum-zirconia type in which the zirconia is said to cause the thermal expansion to be reversed between 1,000 and 1,200° C.⁷ Zircon refractories can also be used for alkaline glasses in those parts of the furnace not in contact with molten glass. They are also recommended for furnaces making frits for vitreous enamels. An addition of 5 per cent. zircon to gas fire radiants is said to extend the firing range without loss of spalling resistance.⁸

Other applications quoted by the suppliers of zircon are in plant preparing calcium metaphosphate and roasting materials like tungsten ores, silica gels and fluorescent chemicals. Raschid rings for chemical plant and pyrometer and combustion tubes are other uses. The use of zircon in refractories used for tunnel kiln furniture has enabled their thickness to be drastically reduced, thus increasing the payload for the same fuel costs.

Zirconia Refractories

Where greater refractoriness is required zirconia is superior to zircon and is, of course, more expensive. Zirconia melts at approximately 2,700° C. and can be used up to 2,500° C. Values of specific gravity from 5.49-6.0 are given in the literature. The other properties of the oxide together with literature references are tabulated by W. A. Archibald and E. J. D. Smith.¹⁰

Originally there was a difficulty in the use of zirconia in that it underwent a reversible change at about 1,000° C. giving a change in crystalline form. This often caused cracking. In 1929 it was found that small additions of magnesium, calcium or yttrium oxides could stabilise zirconia.¹¹ Fused stabilised zirconia was made in America in 1946. This stabilised zirconia contains 94.95 per cent. ZrO_2 , 4.5 per cent. CaO , 0.14-0.75 per cent.

ZIRCONIUM SILICATE COLOURS

Colour	Light blue				Light green			
Firing time (hours) ...	4	4	4	4	4	4	4	4
Firing temperature (°C.) ...	750	750	750	750	750	750	750	750
<i>Composition</i>								
Ammon. vanadate (NH ₄ VO ₃) ...	10	10	10	—	10	10	10	10
Zirconia ZrO ₂ ...	125	125	125	125	125	125	130	130
Silica SiO ₂ ...	5	—	—	5	—	5	—	—
Sod. fluoride NaF ...	60	60	60	60	60	60	60	60
Lithium fluoride LiF ...	—	5	—	—	—	—	—	—
Pot. fluoride KF ...	—	—	6	—	—	—	—	—
Vanadium pentoxide V ₂ O ₅ ...	—	—	—	9	—	—	—	—
Zirconium fluoride ZrF ₄ ...	—	—	—	—	170	—	—	—
Sod. carbonate Na ₂ CO ₃ ...	—	—	—	—	4	—	—	—

SiO₂ together with small amounts of titania (TiO₂) and iron oxide. This material melts at 2,550-2,600° C. and has a true specific gravity of 5.6. Its thermal conductivity is lower than that of fixed magnesia and alumina. Refractoriness under load is good, failure occurring at 2,110° C. with a load of 10 lb./sq. in. and at 1,950° C. with 40 lb./sq. in. The stabilised zirconia has good resistance to thermal shock and it is chemically fairly unreactive at high temperatures. It has been used in chemical plant, e.g., nitrogen fixation plant¹² and for the parts of jet and rocket motors and gas turbines which have to withstand the eroding effects of hot gases. Washes of zirconia have been shown to prolong the life of furnaces operating at high temperatures since the material offers resistance to coal ash slags.¹³ Zirconia crucibles have withstood thirty heats in melting platinum¹⁴ and it is reported that an electric furnace with a zirconia hearth has done more than 1,200 heats without repairs when melting steel.¹⁵

Making Methods

Zircon and zirconia have no plasticity. It is, therefore, necessary to use bonding material, either clay or some organic material. A 2 per cent. solution of zirconium chloride has also been recommended. Pressing, extrusion and slip casting are the methods preferred. Pressures up to 6,000 p.s.i. with an organic binder, e.g., dextrin have been described. Slip casting of zircon and zirconia can be done in plaster moulds, but close attention is required to the control of the slip.¹⁶

Zirconia for Colours

Zirconia is used in a stable series of yellow, green and blue colours suit-

able for body stains, ennobles and underglaze and enamel decoration. These have been described in patents granted to the Harshaw Chemical Co., U.S.A.¹⁷ The patent for greens and blues covers the use of zirconium, silicon and vanadium oxides and compounds which can yield these in chemical reactions. The zirconia is present in amounts equal to 0.8-8.5 the weight of silica and the vanadium pentoxide is 3-10.5 per cent. of the combined weight of silica and zirconia. Calcining a mixture of vanadium, zirconium and silicon oxides gives greens, while for blues alkali is added equal to 0.5-5 per cent. of the combined weights of the above three oxides. Examples quoted in the patent specification are given in the accompanying Table. Calcination may be done between 550° and 1,300° C.

The yellow pigment is described in U.S. Patent 2623833 dated 30/12/52. (B. W. King and A. O. Tesar, Harshaw Chemical Co.). The composition is given in the specification as (ZrO₂ + Na₂O) 60-90, V₂O₅ 4-30, TiO₂ 2.5-3.5. Zirconia with 0.2-2.0 parts of Na₂O gives a yellow when fired. Inclusion of titania improves the colours. A vanadium yellow has also been described by P. A. Huppert¹⁷ by heating lead oxide (PbO) and zirconia with vanadium salts.

E. Biagiotti and G. Grungo¹⁸ have used zirconia in preparing chrome pinks.

Zirconia as an Opacifier in Glazes and Enamels

Opacification is caused by reflection, refraction and diffraction of light by particles embedded in the glassy matrix in glazes and enamels. The light is scattered or diffused, thus destroying

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the transparency. To do this the refractive indices of the particles and the matrix must be numerically different. That for the glassy matrix is usually between 1.50 and 1.55 whereas tin oxide has a refractive index of 2.04, titania 2.52-2.76, antimony oxide 2.60 and zirconia 2.40. Zirconia, therefore, ranks high in the list of possible opacifiers.

Zirconia can be included in frits for the iron enamelling trade which are of the self-opacifying type, that is the opacity is developed on fusing on the metal by recrystallisation. A typical white frit is given below:¹⁸

Borax	...	...	44
Pyrophyllite	...	...	36
Aluminium hydrate	...	...	4.5
Sod. nitrate	...	...	3.5
Limestone	...	...	8.8
Zinc oxide	...	...	5.0
Cryolite	...	...	14.0
Zircon fluor	...	...	12.3
Fluorspar	...	...	5.0

This frit has a wide range of safety in firing. Zirconia can also be added to the mill batch usually as 2-4 per cent. on the weight of frit (rather more with acid-resisting types). The present tendency in this country is, however, towards titania opacified enamels, which are acid resisting and give a better opacity.

Zirconia is also used as an opacifier in glazes. It is not as effective as tin oxide as it needs a larger quantity for opacification, but on balance is cheaper. It is not used in higher temperature glazes containing boric oxide as clear patches appear. It can be used in fireclay sanitary types without trouble, and has the advantage that it does not affect green colours as tin oxide does (formation of chrome-tin pink). Generally, 3-6 per cent. is used, but above this the glaze reflectance falls off. It is important to select the right grades of zirconia to get the best opacification, as the fineness of grinding affects the results.

Zirconia for Polishing and Grinding

Special grades of zirconia have recently been used for polishing glass in place of the more expensive cerium oxide. A mixture of 1½-3 oz. in a pint of water is recommended as a polishing slurry, or if necessary ¼ per cent. of sodium alginate can be added to pro-

mote better suspension. The hardness of zircon sand enables it to be used in some metal cleaning processes by blasting. Blasting with steel grit alone often leaves a smudge on castings. This can be removed by adding sand to the grit. Sand, however, is not liked on account of the danger of silicosis. Zircon sand is free from this danger and, being hard as well, is now being used with steel grit for cleaning castings.

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EXCLUSIVE**"Ceramics—A Symposium"****An Appreciation**by **L. R. BARRETT, M.A., B.Sc., M.S. A.R.I.C., M.Inst.F.**

(Lecturer in Refractories and Silicate Technology at the Imperial College of Science and Technology)

PART 1.

THE publication of this book is a milestone in the evolution of ceramics as a science in Great Britain. It recognises—as does its sponsor, the British Ceramic Society—that the scientific study of pottery, refractories and heavy clay products must be on a common basis.

Twenty-nine reviews have been made of most aspects of ceramics by thirty authors and put together by A. T. Green, Honorary Secretary from 1947 until the present year, when he became President, and G. H. Stewart, Honorary Editor of the Society Transactions. The handsome, 877 page volume commemorates the Jubilee of the Society in 1950 and, as Stewart wrote then in the Proceedings, is intended "as a fitting tribute to the Society, and as a valuable survey of work carried out during the first half of the twentieth century that will make possible the achievements of the second half."

The Society was formed as the North Staffordshire Ceramic Society in 1900 but, in 1905, the New Zealander, J. W. Mellor, became Secretary and its name was changed to the English Ceramic Society. Under Mellor's guidance the science of ceramics blossomed and many of the flowers appeared in the Transactions, during the years when he was at work in what became the Pottery Department of the North Staffordshire Technical College. It is to be regretted that Mellor did not find it possible to write a book on the science of ceramics in the nineteen-twenties, though the section on "Silicates" in Vol. VI of his stupendous "Comprehensive Treatise on Inorganic Chemistry" has been a good deal used (and not always acknowledged)

by writers anxious to impress with their erudition. This reviewer is probably not alone in coming away disappointed from a perusal of general books on ceramics available in the nineteen-thirties. There has been too in recent years a saddening reliance placed on American writers who, however excellent, seldom give due credit to European (and frequently earlier) contributions to their subject. Professor F. H. Norton is one exception.

It is known to all that in many of the services that Mellor performed for the ceramic industries he was ably assisted by A. T. Green. None was more conscious of the need for a major British work than Green but by the nineteen-thirties it was clearly a mammoth task for one man to cover all aspects of ceramic technology. Credit for the genesis for the present work must be given to Green, who has been able to secure the services of an impressive array of authors, each expert in his field.

The book is divided into four parts. The first contains seven contributions on the more fundamental aspects common to the succeeding three sections on pottery, refractories and heavy-clay wares, corresponding to the four sections of the Society, a Basic Science Section having just been added. The section on refractories is most comprehensive and covers the field by taking the various commercial refractories products in turn, passing on to the application of refractories in the iron and steel and gas industries, and concluding by chapters on thermal properties and testing. Sections on mechanical properties (A. I. Roberts has written extensively on this subject)

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and the application of refractories in the glass industry might have been added. This break-down of the subject gives full scope to consider the historical aspects of the individual materials, but an alternative method is to consider the manufacturing process from raw material, through moulding, drying and firing to testing and use. Two contrasting arrangements are used by J. H. Chesters on steel furnace refractories and J. Mackenzie on refractories for blast furnaces.

In the pottery sections one would have expected sections from different branches of the industry such as the earthenware, fine china and wall tile sections but there are instead short contributions on table ware and a very long one on electrical ceramics which have not been dealt with extensively previously in British publications, except by E. Rosenthal. Major contributions in this section are on drying of all ceramic products and firing of pottery.

The heavy-clay section is briefer as befits a branch upon which relatively less scientific work has been done. Here the subject is considered in relation to the manufacturing processes, but drying is discussed by C. E. L. Franklin in the pottery section. To balance this E. Rowden incorporates an account of the firing of refractories in his chapter on brick kilns in this section. The concluding chapter is one of the best in the book on the nature and testing of clay building materials by B. Butterworth. One misses the name of H. H. Macey in this section on moulding and drying of heavy clay products.

Some account will now be given of the individual contributions, but it should be made clear that it is not possible to do more than whet the intending reader's appetite.

Geology

A gradual change has been taking place in our conception of how a scientific approach can be made to the arts of the potter and brickmaker. This is nowhere more evident than in the general section, which is first rate, though the first chapter on "Geology and Ceramics" is disappointing. This is written from the standpoint of the pure geologist and fails to convince the

reader as it should of the vital importance of the geologist to the ceramic industry. An economic geologist of long experience could have recounted many instances where his profession had come to the rescue of the manufacturer cut off from his usual supplies or faced with developments demanding improved raw materials. This becomes apparent from a perusal of the chapters on silica and basic bricks. Until the last few years research work involving contrasting raw materials has far too often neglected the geological aspect, but the work on clays by A. L. Roberts and co-workers at Leeds and B. Butterworth and co-workers at the Building Research Station are instances where this fault has been corrected. W. Davies has shown how intimately the quality of silica bricks is governed by the geological history of the quartzite.

Mineralogy—Silica

One of the best known and most used pieces of work in silicate science is that done by C. F. Fenner in 1912 at the Geophysical Laboratories at Washington, D.C. on the stability relations of the pure silica minerals. After some initial reluctance, as A. E. Dodd relates, on his side of the Atlantic, Fenner's results were everywhere accepted from about 1920 until almost the present day. No doubts need be entertained of the broad truths of Fenner's results, but in detail some amendments must be written in. Fenner reported, for instance, that tridymite showed two inversion temperatures at 117° C. and 163° C., but it is now known there may be others, not necessarily exhibited in all samples, in the range from 100° C. to 500° C. It is certain that the mechanical restriction of surrounding glass plays a part as shown by E. H. Badger, W. Lewcock and J. H. Wylde in 1946. Impurity ions trapped in the lattice seem to be important too. The lower the temperature of formation the lower tends to be the range of inversion temperatures. The "163° C." effect was shown by A. Q. Tool and J. B. Saunders (1938) to be associated with a platy form of tridymite and the 117° C. form was associated with wedge-shaped crystals frequently found in refractories.

Cristobalite, too, has two inversion

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temperatures as Fenner suspected and as R. Weil (1928) and A. L. Roberts and co-workers (1946) have shown, latter by the elegant differential thermal analysis method. It is not surprising that very careful work shows that the inversion temperature of quartz may vary by 1-90° C. (Tuttle, 1949) and even show two inversions (I. C. McDowall and L. R. L. Dunn, 1947).

X-ray Crystallography

In the period under review X-ray crystallography has developed steadily from the prediction of Max von Laue in 1912, that X-rays could be diffracted by a crystal. All ceramic raw materials are crystalline, as are wholly or in part most products made from them. H. M. Richardson's account of the diffraction of X-rays by crystals and the use that can be made of Debye-Scherrer powder photographs is an excellent introduction to the subject which should be clear to any reader without prior knowledge.

Popular accounts of the electron microscope—which gives a visual image much like an ordinary optical

microscope—have helped to familiarise us with its nature. It has so far proved much less useful in ceramics than the X-ray crystallographic apparatus, but the latter has the disadvantage of giving a "picture" of the crystal in which the points at which atoms are situated do not appear directly but only as line (or spots) which give the distance apart of rows of atoms and, therefore, the "picture" needs measuring and computing. But for identification purposes this "picture" is just as good as a finger-print, so that a file of finger-prints or "pictures" of the substances likely to be met with enables identification to be made in a few moments and just as directly. Most work is done this way. A further aid is the card-index of computed spacings of several thousand crystal lattices compiled by an international committee. A mixture can be analysed but, as Richardson warns, some substances do not produce such sharp and intense "pictures" as others, so that for instance 5 per cent. of dicalcium silicate would be missed but 1 per cent. of quartz found.

(Part II will be published next month.)

REFRACTORY RECUPERATORS

by F. H. CASS, N. L. FRANKLIN and A. L. ROBERTS

A RECUPERATOR is a device for increasing the availability of heat or cold in a process and its performance may in theory at least, be judged by the way in which it performs this function. It is customary to reserve the term recuperators for those units in which, under steady operating conditions, heat storage is not involved, and to describe units involving heat storage as regenerators. An intermediate type is the reversing flow heat exchanger. The commonest type of recuperator is that in which two fluid streams exchange heat through a partition which prevents mixing of the two streams, but the upper part of the shaft of a lime kiln, cupola or blast furnace, or the inner wall of a permeable furnace can all be regarded as recuperators. In those units in which the raw materials are fed into a shaft the recuperation takes place between the product gases and the stock, the latter being preheated and the heat demand at the highest temperature reduced. In a permeable furnace the inner wall surface is brought to a temperature which closely approaches that of the gases and the heat transfer to the furnace charge is thereby increased. Where recuperation takes place between two fluid streams the proportion of the heat of combustion of the fuel which can be delivered to a stock at a given temperature is increased, or for a fixed heat demand the fuel requirements are reduced.

Heat Exchange Between Two Fluids

Preheat temperatures up to about 600°C. at atmospheric pressure can be obtained in metal recuperators, and wherever a common metal or low cost alloy will withstand the operating conditions for an economic period its use is to be preferred. For higher temperature conditions some

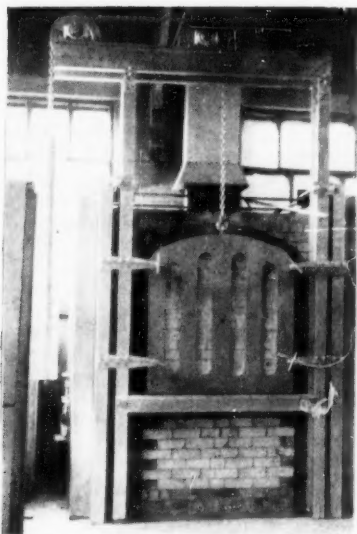
form of refractory material must be employed unless the process product is sufficiently valuable that a short working life can be tolerated. Refractory materials suffer from the following disadvantages as heat transfer partitions.

1. Low thermal conductivity.
2. Low mechanical strength.
3. Poor qualities as a fabrication material.
4. Slag attack at high temperatures.
5. Thermal shock.

The thermal conductivity of refractory materials (excepting carbon and carborundum) fall in the range 0.5-2.0 B.Th.U./ft. hr. °F. which is less by a factor of 20 than the common metals and alloys used for lower temperature conditions. In addition because of lower mechanical strength the partition thickness in a refractory recuperator is about 5 times greater than that in a metallic unit. The conduction component of the transfer resistance in ceramic recuperators is therefore about 100 times greater than the corresponding component of a metallic unit. The convectional transfer on the surface of the partition is theoretically within the control of the designer, but the limitations of pressure drop imposed by natural draught operation generally result in transfer coefficients of 3-10 B.Th.U./ft.²/hr. As a result the film resistances and the conduction resistance are of the same order of magnitude and the overall transfer coefficient can rarely be increased by a factor of more than 1.5 unless all three resistances are simultaneously reduced. In particular minor changes in the conductivity of the partition will have a small effect on recuperator performance which will be negligible unless accompanied by modifications in flow conditions. With such low overall transfer coefficients the absolute efficiency of heat exchange is inevitably low unless units of very large surface area can be constructed.

From a paper to the Institute of Fuel on 26th January at the Institution of Mechanical Engineers, London.

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If this is achieved by increasing the flow path then spatial considerations lead to a multipass design, commonly of the cross-counterflow type and an appreciable proportion of the available pressure drop may be expended in changes in flow direction and in turbulence which, being unassociated with the heat transfer surface has a relatively small effect on the transfer coefficients. The alternative procedure of using extended transfer surfaces is restricted by difficulties of fabrication, or by the relatively low conductivity of the solid, and by the presence of dust or chemically active materials in the gases. When the refractory partition is likely to be attacked recuperators are usually unsuitable because extensive leakage between the air and waste gas streams will result; in such cases regenerators are used. If solid deposits occur on the partition surface the regenerator is again to be preferred since the only effect is to increase the thickness of the packing and the pressure drop. An increase of the packing dimensions decreases the regenerator performance, but the effect is small provided that the deposit is consolidated and of a thermal conductivity comparable with the packing whereas with a recuperator the deposit represents a direct increase in the heat transfer resistance.

Design Factors in Recuperators

In considering factors affecting the optimum design of recuperators the usual engineering procedure of minimising the total operating and capital cost can be adopted only after a number of other factors have been considered. Firstly, unless a furnace is operating at such a high temperature that the available heat from the fuel would be extremely low without recuperation the recuperator cannot improve the quality of the product but may even reduce it unless the recuperator is completely reliable. For high cost products the fuel saving resulting from the use of a recuperator may be offset by increased shut-down times. Again, those industries which have statutory commitments or in which a unit remains in continuous operation throughout its working life tend to prefer simple if less efficient recuperator designs

used in conjunction with W. H. Boilers. Finally, since the required life of the recuperator may be several years, new or improved designs are not easily tested. Subject to these conditions the best design will be one in which installation costs and cost of fan operation is weighted against heat recovery, or, if a Waste Heat Boiler is fitted, against improvement in quality of the heat recovered.

To determine the surface requirements for a given heat exchange performance a mean driving force and a mean transfer coefficient must be determined. (The mathematical implications were then considered.)

Ceramic recuperators are commonly employed to preheat only the air supply to a furnace and if all the furnace combustion products pass through the recuperator it will be out of balance, the ratio

Waste Gas Heat Capacity Air Heat Capacity

being about 2. The temperature at which the waste gases leave the recuperator is therefore unlikely to be less than 600°C. for an entry temperature of 1,000°C. If the waste gases flow with low pressure drop in 10 in. diameter ducts the radiation component of the transfer coefficient may be as high as 10 at the hot end and 3 at the cooler end. Such an arrangement makes it possible to devote most of the available pressure drop to the air side of the recuperator where it is most usefully employed. The overall thermal resistance is the sum of the film and conduction resistances together with the resistance due to dust or other deposits. The conduction resistance per unit area can only be decreased by increasing the thermal conductivity or decreasing the thickness of the partition. The former is precluded except by variation in porosity if a pure ceramic is used and metal ceramics are probably unsuitable for economic reasons. A reduction in the partition thickness can only be made at the expense of structural strength and reliability, although extended surfaces can be made to provide improved mechanical strength, a smaller effective partition thickness and a higher film coefficient per unit normal area of transfer surface. The alternative

method of increasing the film transfer coefficient, that of increasing the fluid velocity, is not attractive since it involves an increase in the number of passes and of the pressure drop for a given performance. In examining the desirability of extended surfaces on ceramic shapes the following factors must be considered.

1. The mechanical strength of the resulting design.
2. The fabrication difficulties.
3. The effect of the increased surface on pressure drop.
4. The effect of the increased surface of the film coefficient.
5. The effectiveness of the increased surface produced.

The extension to the surface may be protected from handling damage as in the Stein type of brick, where the fins on the air duct are united to completely subdivide the duct or may consist merely of fins. In the latter case only low aspect ratio fins are suitable although these can result in a considerable improvement in the heat transfer. The principal load on the recuperator shapes when assembled is vertical, so that only vertical fins will appreciably affect the strength of assembly. Because of differential buoyancy forces and increased leakage it seems undesirable to use a multipass system in which the passes are vertical whilst the fin axis must be in the flow direction so that in a horizontal pass the fins would provide little or no additional mechanical strength. In the Stein and the Teisen recuperator where extended surfaces are employed the waste gas is multipass crossflow whilst the air flow is single pass vertical, and the waste gas ducts are of proportionately larger cross sectional area compared with the area for air flow than would be required by the relative volumes of the flows involved. Only the air side surface is extended. From the viewpoint of fabrication it would probably be relatively simple to produce shapes in which one surface was provided with triangular fins $\frac{1}{2}$ in. long and $\frac{1}{4}$ in. at the base, but more difficult to provide both surfaces with these fins if the fin axes were at right angles.

If the fins are so designed that flow separation does not occur then

vortices are not shed into the gas stream to increase the pressure drop without a compensating increase in heat transfer. For metal fins an air-foil shaped cross section in the direction of flow can be used and separation minimised. With ceramic construction continuous flat fins of rectangular or triangular cross-section across the flow direction appear most suitable. If no separation then occurs the increase in pressure drop on extending the surface should be approximately proportional to the new surface created, though tests on proposed shapes are usually worthwhile. The effect of the shape of surface on the transfer coefficient does not appear to have received detailed investigation. In those cases where the flow cross-section is completely subdivided the mean hydraulic diameter of the sectors can be used or if the fins are short in the direction of flow the transfer coefficient is known to be little affected so long as the spacing between the fins is of the order of the boundary layer thickness. For continuous fins in long ducts the flow will be fully developed and the available data indicates a variation of transfer coefficient over the length of the fin. For the very stubby fins which are likely to be most suitable in ceramic construction this effect is probably not important.

The author dealt with flow distribution saying that all discussion of heat exchanger design presumes a knowledge of the heat capacities per unit time flowing in the elements. In order to predict transfer coefficients in cases where radiation is not the dominating mechanism the fluid velocity in the elements must also be known. If the flow path for a fluid stream consists of a single channel then the flow of heat capacity and the fluid velocities are determined from the end conditions and available pressure drop. If however, there are parallel or alternative paths for the gas flow then the distribution of the fluid between the various paths will depend upon the resistances involved and the pressure difference available over the alternative paths. This pressure difference will include the effect of buoyancy forces; for a series of similar vertical parallel ducts in which a gas is being heated equilib-

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rium will not be achieved with equal gas flow through the individual ducts unless the heating conditions are the same for all ducts.

The velocities which can be obtained in recuperators are dependent upon the source of draught available.

To consider the air velocities actually obtained, due allowance being made for frictional loss, duct dimensions and surface conditions must be specified.

The Permeable Wall Recuperator

The permeable walled furnace has been mentioned as a special form of recuperator increasing the availability of the combustion energy by reducing the temperature difference necessary between furnace atmosphere and the heat sink. Such a furnace will only be effective at temperatures at which radiation is the important transfer mechanism and would be provided with orthodox recuperators on the combustion products.

Alternative Arrangements of Recuperation

Since the heat capacity of the combustion products is usually about twice that of the air to be preheated a simple recuperation process can never be reversible. For a furnace with exit gases at $1,000^{\circ}\text{C}$, perfect recuperation would leave the combustion products at 500°C , the highly irreversible heat exchange resulting in a reduction of the availability of the heat. For the larger furnaces this low grade heat is recovered by waste heat boilers which have a low inlet temperature as compared with normal boilers and high pressure drops (3 in. w.g.) have to be made available in order to utilise this heat. The advantages of this form of waste heat recovery depend upon the works steam demand and upon the continuity of supply from the W. H. boiler. As a disadvantage it must be noted that the fuel by which the furnace is heated is usually of a higher grade than that from which an alternative supply of steam could be provided. The common arrangement is obviously convenient, but two alternatives may merit consideration.

1. Reducing the irreversibility of the heat exchange process in the

recuperator by reducing the flow of combustion gases through this unit. The remaining combustion products could then be fed directly to a boiler giving better heat transfer in the steam raising unit. Also because the recuperator would be more nearly balanced in the heat capacities of the flow streams the temperature difference could be made equal along its length. Only the hot end of the unit need then be constructed in ceramics, about half of the total heat transfer being achieved in metal recuperators. Obviously the pressure drop over the recuperator would be increased by this procedure and additional metallic recuperators would be required. Against this the pressure drop and volume of products handled by the W. H. boiler would be reduced and it could be more simply constructed because of the higher temperature differences available. A somewhat more radical alternative would be the use of the diverted combustion gases to a closed cycle gas turbine heat exchanger.

II. In cases where the furnace is producer fired the balance in the recuperator might be nearly restored by increasing the total air volume and diverting that not required by the furnace to the producer. By this means the blast saturation temperatures of the producer could be increased, additional water gas being produced at the expense of preheat introduced in the air. This alternative is attractive since it allows works steam to be produced from low grade fuels and economises in higher grade producer fuels. To achieve the increased heat exchange a greater recuperator surface is required, but it might prove attractive to balance the recuperation only at the low temperature end where metal heat exchangers could be employed. Above the safe limit for metal heat exchange the producer air could be diverted and only the furnace air would be required to pass through a ceramic exchanger. Under these conditions the heat exchange to be carried out in ceramic materials is considerably reduced although the area required is not proportionately reduced due to the smaller mean temperature differences which are involved.

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- Fully proved in operation
- Open and block handles
- Bone China, Earthenware, and Porcelain
- Less loss and higher quality
- Unskilled labour

British Patent No. 593 520.
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In neither alternative is it desirable to balance completely the recuperation even if this were practicable since the minimum safe temperature to which combustion products can be reduced may be conditioned by their effect upon the metallic recuperators. If, to prevent the trouble arising, a minimum temperature difference at the cold end of the unit is required the mean temperature difference and the degree of preheat may be varied by unbalancing the exchanger to a limited extent.

Conclusions

The transfer coefficients in many existing refractory recuperators are low and the capital cost of recuperation is therefore high. The principal transfer resistances are those of the partition and of the air side film. Increase of the air side coefficient can be achieved by allocating increased pressure drop to the air side of the recuperator. Calculations suggest that this pressure drop can best be utilised by extended surface in the air ducts since a high preheat temperature could then be achieved in a single pass exchanger. Since the gas side transfer can be achieved largely by radiation at higher temperatures it is of advantage to increase the radiational path length and reduce the pressure drop on the gas side by using large diameter tubes. Decrease in the partition resistance can only be obtained by reducing the partition thickness, and extended surfaces would be most advantageously employed where they could provide additional mechanical strength for the partition. The lack of balance in the flow of heat capacities in many ceramic recuperators leads to a high exit temperature for the waste gases and makes metal partitions unsuitable for most of the required surface. Where a demand exists for additional preheated air the heat capacities might be brought nearer to equality. Although the effective temperature difference would then be reduced and the partition surface requirements increased the increased surface could be of finned metal construction and of compact design with relatively high transfer coefficients provided the available pressure drop were increased.

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Fisher and Ludlow Ltd., of Birmingham, announce that they have now signed a contract with Sir Robert McAlpine and Sons Ltd., of London, for the erection of a factory at Ajax, Ontario. This factory is to cater for the growing demands of their Material Handling Division, which is now firmly established in Canada. Its Flowlink chain conveyors, Flowline belt conveyors, Flowstack pallets and Fisholow material handling equipment have received wide acceptance from Canadian Industry. The factory is being built on a large site with ample area for extension, and is serviced by a spur of the Canadian National Railway. The building itself is of the most modern design, the structure being entirely of steel, the framework being completely independent of the outer walls. These walls are of masonry and glass.

Apart from its primary function of providing the most efficient manufacturing and storage space, this plant will be used as a demonstration centre for Fisholow equipment.

The Drying of Tableware and Other Ceramic Goods

By the Jet Drying Method

by W. HANCOCK, M.I.B.R.E., A.M.I.E.E.

IN previous articles of this series, the general principles of drying by high velocity directed air jets have been outlined; and the reasons why rapid drying can be consistent with safe drying were discussed. (CERAMICS: November and December, 1953.) The practical methods of achieving rapid drying, with low loss, of cups, saucers and of large and small flat-ware were discussed.

The present article deals mainly with the jet drying of oval shaped

principle used in conjunction with drying stoves of rectangular plan would be preferable to the circular rotating dobbin dryers used for the general run of flat and saucers.

5. The greater thickness and weight of dishes calls for slower drying than with flat-ware.

The Combination Truck and Stove Jet Dryer for Dishes

The normal jet drying stove for dishes, and bakers is 4½ ft. wide by

4.—JET DRYING OF DISHES, DEEP JIGGERED WARE AND ELECTRICAL PORCELAIN

articles like dishes, and bakers; and of some electrical porcelain pieces, which by reason of shape, size, cost and production in smaller numbers require and merit specialised treatment.

Differences between Dishes, etc., and Flat-ware

1. Compared with flat-ware, dishes and bakers are required in relatively small numbers. Thus, in a normal dinner service, some 70 per cent. of the pieces will be flat-ware; and only about 6 per cent. dishes. This 6 per cent. may be made up of three or more sizes: 10 in., 12 in., and 14 in., or larger.

2. Dish making is a slower operation than flat making, and requires more operative skill and attention.

3. To synchronise with the much larger production of flat-ware, the drying of dishes, etc., can be appreciably slower, provided it is perfectly safe and economical.

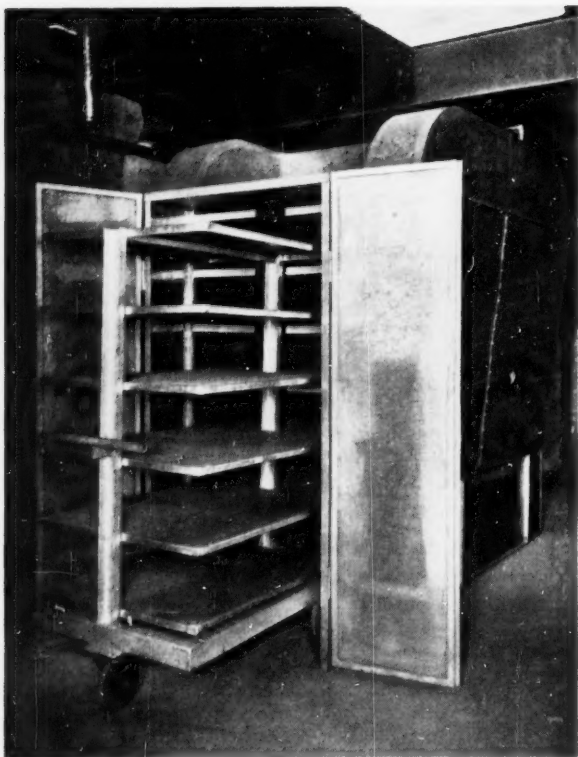
4. Reasoning based on economy of floor space suggested that the truck

7 ft. long, occupying a floor area of 31½ sq. ft. The trucks are of a light construction clearly indicated in Fig. 7. These trucks are of sufficient length to occupy the stove space and carry six shelves. Each shelf will hold two rows of moulds and articles, the number of moulds per shelf varying according to the size of the mould. Thus, for the large dishes (14 in. trade size), each shelf carries two rows of three moulds, i.e., six articles per shelf or thirty-six per truck.

With the smaller dishes (10 in. trade size), each shelf will hold twelve moulds, or seventy-two dishes per truck. With the still smaller bakers, the truck capacity rises to 108 articles.

Outside the stove, the trucks are placed conveniently close to the jigger, and carry empty moulds. The operative removes a mould from a truck, makes the article and replaces mould and article back on to the truck, repeating this operational sequence until the truck is filled.

The loaded truck is then pushed into an empty stove, each side of each



O

Fig. 7

O

shelf coming under a fixed hot air jet system.

The Stove Construction

The stove construction will be understood by referring to Fig. 7, or perhaps better still to Fig. 8.

From these it will be seen that each stove has twelve "shelves," six projecting towards the centre line from each side. These shelves are hollow and are perforated with jet orifices on their lower faces. Being hollow, the shelves act as conductors of hot air from the two air reservoirs which form the two sides of the stove. These air reservoirs receive hot air from the fan in the battery type heaters situated above the units.

The fan itself picks up part of its air through two slots which run from the top to the bottom of the entrance to each stove, this suction intake preventing blow out of hot air from the stoves into the shops.

The remaining air intake to the fan on the suction side is through open ducts in the roof of the drying chamber.

The air movement system is completed with a bleed-off from the pressure side of the fan to the atmosphere.

The air temperature is controlled on the delivery side of the fan by a Spirax-Sarco steam supply thermostat, which requires little attention after being set to provide the correct dry bulb temperature for the air passing to the jets.

Synchronising of Making Rates with Rates of Drying

Preliminary factory observations coupled with time study of making and drying rates for the range of articles between the largest dishes and the smallest bakers, suggested that the best compromise as regards size of truck and stove capacity would be met by a stove 4½ ft. wide,

7 ft. long and 10 ft. high; the top shelf of the truck being about 5 ft. 6 in. above floor level.

Thus, in actual practice at a large earthenware factory, it is found that the time taken to make thirty-six 14 in. dishes is approximately the same as that for making seventy-two 10 in. dishes or 108 bakery; while the maximum safe rate of drying for each size corresponds roughly with the making rates for the given numbers of the different individual sizes and shapes.

In this way, only one size of stove and truck was required to deal with the drying of the whole range of dishes and deep jiggered ware, a practical finding which had the great advantage of needing only one size of truck to fit any number of drying stoves.

For large production factories, where a number of stoves are required, it may make for efficiency to separate the stoves by a distance which enables spare trucks to be garaged between adjacent stoves, as shown in Fig. 8.

In this way, any moulds stored on the spare trucks will be kept dry and

ready for immediate use as demand arises.

Comparative Drying and Fuel Data

Dimensions of the jet truck dryers for dishes, and general production data are set out in the tables below, with comparative data for the older traditional type of truck stove dryer.

In considering these data, three points are worthy of special emphasis:

1. Whereas four traditional dryers were required for one operative, 1½ jet dryers dry the same quantity of ware in much less time, thus yielding an economy in floor space of over 50 per cent., and requiring fewer moulds for a stated output.

2. The traditional dryer required nearly four times as much fuel, as the jet dryer expressed as B.Th.U's. per lb. of water evaporated, and four times as much steam, to dry a given number of articles.

3. Basing calculations on 10 in. dishes which contain 7 oz. of water as made; and steam at 6d. per therm (100,000 B.Th.U's.), each jet stove will show a cost economy in steam of £1 per 44-hour week; or £50 per

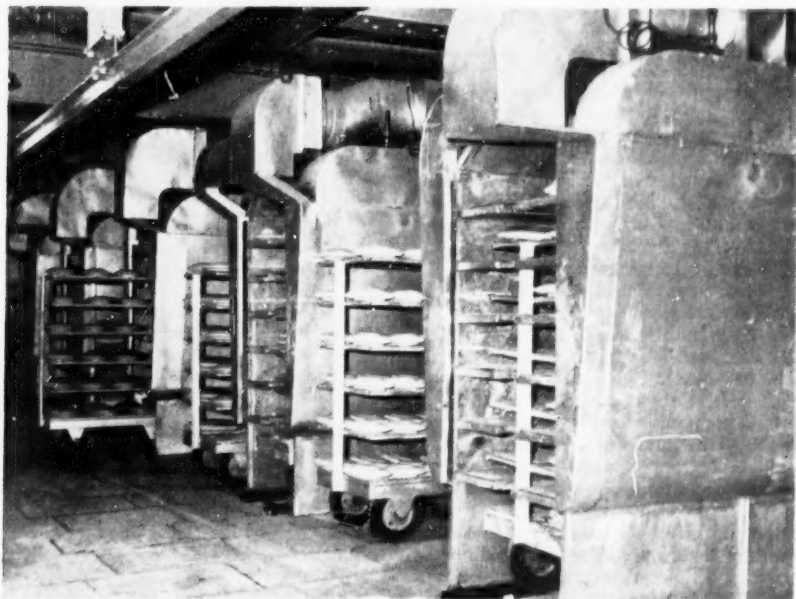


Fig. 8

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DIMENSIONS AND CAPACITIES.

Type.	Sizes.	Floor Area sq. ft.	Type of Heating.	Drying Time hrs.	Moulds in Dryer.
Truck	4½ ft. by 7 ft. by 10 ft.	31.5	Steam: Hot air jet	1½	72
Truck	3½ ft. by 7 ft. by 10 ft.	24.5	Steam pipes Traditional	6	60

POWER CONSUMPTION.

Type	Steam			Power			Total	
	Pressure lb. sq. in.	Con- sumption lb. hrs.	per lb. water evap.	B.Th.U. lb. water	3 phase Amp. phase (416 V)	Kwh.	B.Th.U. lb. water	B.Th.U's. lb. water
Jet	5-10	26.6	1.67	1,670	1.75	0.76	163	1,833
Traditional	5-10	20	6.70	6,700	—	—	—	6,700

annum; to which must be added the additional economies of reduction in floor space, number of moulds per operative, lower losses, straighter dishes and better working conditions.

Electrical Porcelain

A recent American report (American Ceramic Society Bulletin Nov. 1953, p. 374) deals with the advantages gained by replacing the infra-red drying system, by steam-heated jet dryers, for drying 6 in. by 10 in. suspension type insulators, and refractory porcelain ware in both cases to the leather hard condition. A conveyor system was used, but a jet stove system, as for dishes, could be equally effective.

With the refractory porcelain ware, the infra-red drying system which was replaced by jet dryers used 756, 250-watt bulbs at a rating of 2 cents per kilowatt. The operating cost was \$30 per 8-hour day.

The life of the bulb was about 6 months, replacement cost being about \$710. The total operating cost of the infra-red dryer was \$8,980 per year.

Using steam as the heat source, the air jet system cost about \$3 per day on electricity for the fan drive, and about \$1.40 for coal, a total running cost of \$4.40 per day, or approx. \$1,250 per year.

The total investment for the jet installation was about \$7,000, and the

dryer paid for itself within a year.

So far as is known, the hot-air, high velocity, directed jet system has not yet been applied in this country for the drying of special electrical or refractory porcelain shapes; a matter which merits thorough economic investigation.

ELIMINATION OF CEMENT DUST

Mr. Harold Macmillan, Minister of Housing and Local Government, replying to Mr. Dodds in the House of Commons on the 19th January, said that at present there was no known method of completely eliminating dust from cement works. The dust-arresting plant in use at the Thames-side works, when in full operation, attained a high degree of efficiency, but a small proportion of the dust escaped, and the total escaping from a large number of kilns was enough to give rise to complaints in dry weather. These problems were receiving constant attention by his inspectors and the cement manufacturers. In answer to a further question he said that when the machinery was working satisfactorily 95 per cent. of the dust was dealt with, but there was trouble when the machinery was out of action for repairs. He did not think a public enquiry would do the work that could only be done by expert technicians.

Electrical Elements, With Some Application to Intermittent Kilns

by MR. T. E. LITHERLAND

WHENEVER the subject of electrical fired kilns is discussed, one of the first questions usually asked by the ceramist is, "What length of life may I expect from the elements"? Therefore, it is the aim here to indicate to you the method of discerning which element is likely to give reasonable service in ceramic kilns.

There is now an extensive range of resistance materials from which to choose. All these materials have their own peculiarities and in most cases are suitable for one type of work.

The following are the main resistance materials used by furnace builders, together with their maximum element working temperature.

robustness even at maximum temperature. With regard to installation, the methods used have been by suspension from a refractory tube or rod, in other cases laid horizontally in grooved refractories, and in tape form suspended from hangers and hooks. Kanthal Type D wire, whilst having the same maximum permissible elements temperature, is not, by its nature, as robust at high temperature, and it is, therefore, unsuitable for suspending in any way. In order to give good life, it must be supported along its entire length. Very few problems present themselves in this type of firing and element life is usually in the region of five years.

Nickel Chromium Alloy—80/20.

Element temperature up to 1,150° C.

Chromium Aluminium Iron Alloys:

Kanthal Type D. (made in Sweden) ...	1,150° C.
Megapyr II. (made in Germany) ...	1,200° C.
Kanthal Type A. (made in Sweden) ...	1,300° C.
Megapyr I. (made in Germany) ...	1,350° C.
Kanthal Type A.I. (made in Sweden) ...	1,350° C.
Red Fox 135 (British) ...	1,350° C.

The choice of alloy must, therefore, be of the first consideration. The furnace atmosphere in most cases consists of dry air. In such circumstances the choice of alloy will be determined exclusively by temperature and by the method of installing the heating elements in the furnace.

With regard to enamel firing, having a temperature range of 600° C. to 900° C., the choice is between Nickel Chromium alloy 80/20 or Kanthal Type D. The most widely used of these two has been Nickel Chrome 80/20 due to the fact that it retains its

In the case of glost firing, having a temperature range of 1,000° C. to 1,100° C., the choice is between Nickel Chromium alloy 80/20 and Chromium aluminium iron alloy Kanthal A or Megapyr II. Here again, Nickel Chrome has been widely used and more success has been achieved by the use of tape than by the wire form. Element life is usually six to eight months. Kanthal Type A is now in service in many kilns and a life of eight to eighteen months is being experienced. At the temperature of 1,100° C. a life test under intermittent conditions has been carried out using Nickel Chrome 80/20 and Kanthal Type D. The time up to temperature and cooled again was twenty-four

A paper presented to the British Pottery Managers' and Officials' Association, on 1st February, 1954.

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hours. Nickel Chrome gave 156 firings; Kanthal Type D 386 firings; the latter was even then in reasonable condition.

A temperature range of 1,100° C. to 1,180° C. is required for earthenware biscuit firing, and Chromium aluminium alloy Kanthal Type A is normally used in this case with a life of eight to eighteen months.

China biscuit having the maximum temperature of 1,260° C. is one of the highest temperatures permissible with metallic elements. This is again covered by Chromium aluminium iron alloy Kanthal A.1, or Megapyr 1, or Red Fox 135, and anticipated element life is from six to twelve months.

It will be noted from the foregoing that the choice of alloy for a furnace is almost pre-determined for the Kiln builder. For all these temperatures it is wise to have wire of large diameter and as far as possible, wire diameters of 1 in. to 1/16 in. are chosen. Before choosing the wire size, some important details must be decided. In the case of an intermittent kiln:

1. Maximum temperature required.
2. Cubic capacity.
3. Firing time to reach maximum temperature.
4. Time maximum temperature is to be held.
5. Cooling cycle.
6. Number of firings over a given period (say seven days).
7. Temperature difference desired over total setting.

With this information the maximum temperature decides the type of material. The cubic capacity and firing curve to end of soak gives the key to the total Kw loading of Kiln (this is normally in the range of .8 to 1.3 Kw per cu. ft. of loading space). On deciding the Kw loading, then this loading is distributed over the available wall

the bottom and the top of the wall are loaded at a higher rate than the centre portion. It is essential that no part of the wall will radiate heat to the ware at too high a rate, as, in the case of glost firing this will soon cause blistering and many other troubles in the case of other firing processes.

From these details the choice of wire diameters is made; then the design of the element can be formulated.

The most commonly used element is the hairpin spiral, laid horizontally in grooved refractories or insulating material. The ideal conditions for any wire electrically heated is when it is stretched unsupported between two clips in still air at ambient temperature. If a similar wire be coiled into a spiral emission of heat is impeded by the fact that adjacent turns of the spiral are then heated to the same temperature. The temperature difference between two wires of similar characteristics, one straight, the other formed into a spiral, would be that the spiral would attain a temperature 200° C. in excess of the straight wire given equal flow of current.

To ensure that the wire when in service at high temperature does not exceed the maximum, the electrical loading is kept within certain limits. The term used to denote this loading is "Surface loading in watts/sq. in." This is formulated by dividing the Kw loading of an element by the total surface area of the wire in sq. in.

It will be understood that the greater space between adjacent turns in a spiral, the greater can be the loading. A quick method of checking an element is as follows: The minimum space allowable between turns should be sufficient to let a wire of the same diameter be passed through it. The loading for correctly designed spirals should be as follows:

Furnace temperatures up to 1,000° C.	10 watts per sq. in.
Furnace temperatures up to 1,100° C.	9 watts per sq. in.
Furnace temperatures up to 1,200° C.	8 watts per sq. in.
Furnace temperatures up to 1,300° C.	6 watts per sq. in.

space to be used for elements. The way in which this is carried out is most important to the uniform firing of the total setting. No wall space should have a greater loading than 1.4 Kw per sq. ft. and in most cases

The lower the watt loading the heavier becomes the element—it therefore becomes more costly. The above details are given with a view to a good life at reasonable cost.

When spirals are formed in

Chromium aluminium iron alloy, care must be taken not to make the spiral too large in its over-all diameter. The following ratio should not be exceeded regarding mandrell size to wire diameter.

Element temperature to 1,000° C. 4 to 5; Element temperature of 1,000° C. 3 to 4.

Spiral collapse is the usual fault that occurs if the above ratio is not followed. This is indicated by the falling over of the turns against each other and as each turn falls, so it causes a local hot spot and the fault is then progressive along the spiral. It is erroneously thought that a turn falls over and contacts the adjacent turn, thus reducing the total resistance of the element. Under test this has been disproved as when the alloys such as Kanthal are put into service, they immediately form a firm skin of Oxide the contact resistance of which is extremely high. Therefore, the "shorting" out of coils is highly improbable, and the failure is due to the closing of the spiral coils raising the element temperature to beyond its limits.

The main aim when designing an element is to keep the temperature of the wire as close as possible to the furnace temperature. The method of housing is, therefore, very important. Heat can be transferred from the element by three methods: Conduction, Radiation and Air-convection.

The surface area of contact between the element and support is very small—therefore only a small percentage of heat is transferred by conduction. Providing the groove is correctly designed, radiation is the way in which most heat transfer is carried out. Air-convection currents in the case of intermittent kilns are very small so little help is given by this action.

In some cases to enable the convection of air to be used, forced air circulation has been installed by use of compressed air through small jets.

The following information is given as a guide to the difference between furnace temperature and element temperature at the given watts loading:

The above figures can be taken as being on the safe side in a well constructed furnace.

Many factors must correlate to produce a good design for an element, and the last of these is the type of "leadout" through the wall of the furnace.

Many elements are made with the "leadout" being of the same diameter wire as the element—this is not normally good practice as they tend to make the connection outside hot, and thereby give trouble in operation. End connectors should be made of a size large enough to allow the passage of current to the active part of the element without over-heating the lead. A normal lead is three times the cross section of the active part and may be made of either solid rod or by the addition of two wires of the same cross-section as the active wire. The three wire lead is mainly used in cases where the lead must be flexible to enable it to be installed in the kiln. Connection to the lead and the supply lead must be able to give a good area of contact and the rods can be died so as to use two nuts and washers to make this contact.

Rod "lead-ins" require expert welding and the method of preparing the element and rod for welding together is by the following procedure.

Drill an axial hole into the rod of a diameter just large enough to take the wire with a tight fit, this would be about 1½ in. in length. A slot is cut across the rod at the bottom of the hole and another ½ in. from the end—these penetrate to the drilled hole. The wire when inserted into this hole can be welded in two spots.

Chromium aluminium iron alloy undergoes a coarsening of grain structure when heated to the temperatures required on welding, and may become extremely brittle and tend to fracture. This can be prevented by experienced welding operators.

Installation into the furnace needs the same care as that taken in the design and manufacture. The main things with Nickel Chrome is to see that all individual turns are equally spaced and that slight tension is put

Watts loading.	5 per in.	Furnace temp. 1,000°	Element temp. 1,035
Watts loading.	7 per in.	Furnace temp. 1,000°	Element temp. 1,070
Watts loading.	10 per in.	Furnace temp. 1,000°	Element temp. 1,098
Watts loading.	12 per in.	Furnace temp. 1,000°	Element temp. 1,125

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on the spiral. With Chromium Aluminium Iron Alloys greater care is necessary—this material, to enable it to give a good life must be allowed to form its natural oxide skin which is one of its features. The skin will form in an oxidising atmosphere at a wire temperature at approximately 1,000° C. It is advisable, whenever possible, to form this coating before installing the element. With intermittent type kilns, this skin forming can be carried out by coating the grooves with a wash of allumina oxide then installing the uncoated elements. The furnace is then taken up to the required temperature while empty, allowing adequate ventilation during the fire. After this fire, on no account must any attempt be made to alter the element while in the cold state, due once again to the coarsening of the grain structure, and the liability of damaging the skin that should now have been formed. Too much emphasis cannot be placed on this forming of the oxide skin, as the life of the wire would be greatly impaired if it should be placed and fired in an atmosphere liable to attack the material.

Where the element passes through the wall of the furnace to the outside connections, care must be taken to use a tube made of a good electrical insulating material. When connecting to the electrical supply without the use of a transformer it is important to keep the voltage as low as possible across the adjacent grooves. In the furnace a maximum voltage of 60 volts per in. of brick at temperatures of 1,000° C. and over, is permissible. During the past few years, an undue amount of emphasis has been given to this problem of voltage, due to many kilns being constructed by people with insufficient electrical knowledge. In most cases a simple re-arrangement of element connections is all that is required to completely remedy this trouble.

Tunnel kilns have proved themselves very adaptable to mass production in the ceramic industry and very economical in continuous service. This condition can be only met with, however, when sufficient ware is always available—therefore a regular guaranteed market for the finished article is necessary. Should there be a lengthy breakdown of the kiln a serious loss in production is entailed, and continuous

labour and attention is required throughout the whole twenty-four hours. It is clear, therefore, that these conditions can only be met with on large well planned factories. With regard to the small or medium sized factory whose output varies, the suitability of a tunnel kiln is therefore in doubt.

To effect a change from older methods to a new process the chamber or truck type kiln has been developed, and in latter years, the twin type truck kiln. These kilns have many of the advantages of the tunnel kiln, but not the big disadvantage of continuous service. The firing can be carried out automatically with little or no attention. A standard size has been developed having a loading space of 36 cu. ft. per truck. The output of a twin type kiln would be 144 cu. ft. per twenty-four hours on enamel firing up to 850° C.; 72 cu. ft. per twenty-four hours for glaze; and china biscuit 36 cu. ft. per twenty-four hours. The relative electrical loading would be enamel 60 Kw; glaze 84 Kw and china biscuit 96 Kw. With each chamber it is advisable to have two trucks—one being fired, the other being unloaded and replaced with ware ready for firing. A transfer car is necessary to effect the change over of trucks.

From experience it has been found that the change over can take place at relatively high temperatures without detriment to the ware. It is normal to change over at a temperature of 300° C., the fresh truck thereby being run into the chamber at a temperature of 250° C. A great economy is brought about by this method.

The following is the time cycle for fired enamel ware:

Start at 250° C. by putting the loaded truck into the chamber, close and fasten doors (exhaust dampers situated in the roof are left open). The kiln is switched on, and on attaining a temperature of over 400° C., the roof dampers are shut, the fumes having by this time been removed. On reaching the required temperature, the supply is automatically cut off, the dampers are opened to facilitate rapid cooling, the door is also released but not opened until the temperature is down to 450° C.

The time taken to fire enamel is six to eight hours china, and at least eight hours for earthenware. It is in-

advisable to attempt to rush the enamel firing of earthenware.

Firing of glost is by the following cycle. Starting as enamel, 250° C. then up to 450° C. then on to the maximum temperature which is normally about 1,080° C. The soak period (if one is required), can be carried out automatically and no attention is required until the firing is at the end of its soak and cooled to 850° C. The dampers are then opened and the cooling takes the same course as for enamel firing. The time taken for glost firing is usually ten hours, plus one hour soak with thirteen hours cooling and truck change over.

For some years the firing of small articles of china biscuit has been carried out by small intermittent kilns and during the past six months a twin truck kiln has been built by my firm to fire fine china to the maximum temperature of 1,280° C. Few details are ready for publication at the present time, but the following are the results to date.

Hollow ware can be fired at a temperature of 1,230° C. on a forty-eight hour firing cycle (twenty-four hours to maximum temperature twenty-four hours cooling and truck changeover). A longer cycle is required for flat ware and some trouble is being experienced with the development of brown colour with some bodies. Even this trouble is only apparent however, where the standard of selection is of a very high order.

Whenever the subject of fuel costs are mentioned in relation to electricity, it always brings to my mind the saying that there is only one thing wrong with electricity for firing ceramics and that is that it is too dear. This may seem true if one takes the fuel costs only. When the total cost of a particular firing process is used as a basis for comparison, then electricity can be shown in a more favourable light. The higher the temperature required to complete the process, the greater becomes the margin of difference between costs of firing by continuous or intermittent kilns.

The most economical level for intermittents is therefore—enamel firing at 740° C.

Many new methods are being tried regarding kiln construction with the use of grooved insulating refractories on the hot face of the kilns. They

have insulation efficiency, low heat storage, mechanical strength and the refractories can be improved on the surface only by applying a refractory slurry. This surface is suitable for temperatures to 1,500° C. More is being discovered about the type and amount of insulation required for different firing cycles.

There is no doubt that there are many uses for which the truck type chamber kiln can be used in the ceramic industry, and many new developments along this line will be revealed in the near future.

AN ELECTRO-MAGNETIC PERCOLATOR

From Rapid Magnetic Machines Ltd., Lombard Street, Birmingham 12, we have received Publication No. 115R, which deals with the "Rapid" electro-magnetic percolator—a water chute type separator for the extraction of fine iron particles and magnetic oxides from potters' slip, glaze, vitreous enamels, chemicals and other fluids which are to be freed from ferrous contamination.

The liquid or semi-liquid material to be treated flows by gravity through a series of magnetic filters each comprising a number of magnetic screens, which present innumerable "edges" of high intensity. The material is effectively searched and researched as it progressively percolates through each filter unit. The iron particles are attracted and held while the clean material passes forward and is discharged. The extracted particles can be removed at the end of a run by hosing down.

An automatic discharge bridge is incorporated in the unit. This collapses and diverts the flow on switching off, or upon current failure.

The filter units are easily detachable and are interchangeable.

The above is an addition to the already wide range of units which the Company produces in this field.

Pottery Exports. In December, 1953, the value of pottery shipments was £1,808,650, compared with £1,599,996 in December, 1952, and £2,185,371 in December, 1951.

The volume of pottery exports in December was 466,529 cwt., compared with 480,965 cwt. in December, 1952, and 460,391 in December, 1951.

American Ceramic Society

THE following summaries are of papers appearing in the *Journal of the American Ceramic Society*, January, 1954:

Galvanic Corrosion Theory for Adherence of Porcelain Enamel Ground Coats to Steel, by D. G. Moore, J. W. Pitts, J. C. Richmond, and W. N. Harrison (National Bureau of Standards, Washington, D.C.): The galvanic corrosion theory of adherence between ground-coat enamels and steel was investigated as a part of a broad study of the bonding mechanism between ceramics and metals. The theory, which is outlined in this report, is based on the mechanical anchoring of the enamel into the pits formed by the galvanic attack of the enamel on the steel surface. The theory was first examined from the standpoint of the data on adherence obtained in earlier studies at the National Bureau of Standards. In addition, several experiments were performed which demonstrated that galvanic corrosion of the metal base could occur during the short firing times encountered in enamel processing. On the other hand, certain inconsistencies were observed in the data which indicated that the mechanism of galvanic attack followed by mechanical anchoring was not the only important factor affecting the bond strength.

Studies on the Lime-Rich Crystalline Solid Phases in the System Lime-Silica-Water, by G. L. Kalousek, J. S. Logiudice, and V. H. Dodson (Department of Chemistry, University of Toledo, Toledo, Ohio): A study was carried out to ascertain the effects of two forms of silica, quartz and silicic acid, the methods of mixing, and autoclaving conditions on the formation of the lime-rich crystalline hydrous calcium silicates designated as alpha-, beta-, and gamma-type hydrates. The alpha-type hydrates were synthesized from mixtures of lime slurry and quartz in compositions of 1.8 to 2.4 CaO/SiO₂ molar ratios (C/S ratios). This series of compounds, free of all contaminants, showed x-ray patterns containing many or nearly all lines of crystalline Ca(OH)₂. The beta-type hydrates, of which synthetic hillebrandite is a member, were prepared in 1.8 to 2.4 C/S ratios from mixtures of CaO and silicic acid dispersed in water. This series of phases or closely related phases may extend in composition from 1.5 to 3.0 C/S and includes minerals and other synthetic solids previously believed to be distinctly separate phases.

The gamma-type hydrates having compositions of about 1.5 to 2.25 C/S were prepared from mixtures of quartz and CaO dispersed in water and autoclaved at somewhat higher temperatures than the alpha-type hydrates. The gamma-type hydrates contained about 0.3 to 0.4 mol. of water per mol. of compound compared with values of 1.00 to about 1.25 for the other two types of hydrates.

Phase Equilibria in the System Lithium Metasilicate- β -Eucryptite, by M. Krishna Murthy and F. A. Hummel (Division of Ceramics, School of Mineral Industries, The Pennsylvania State College, State College, Pennsylvania): A phase equilibrium study of the join lithium metasilicate- β -eucryptite in the system Li₂O-Al₂O₃-SiO₂ was made by the quench method. The phase diagram was found to be a simple binary with a eutectic at 1070°C. and 57 per cent. eucryptite. The relationship of these data to the ternary system is discussed.

Metal-Ceramic Interactions: III, Surface Tension and Wettability of Metal-Ceramic Systems, by Michael Humenik, Jr., and William D. Kingery (Ceramic Division, Department of Metallurgy, Massachusetts Institute of Technology, Cambridge, Massachusetts): The wettability and adherence of metal-ceramic systems were investigated, using a precise sessile-drop method. The surface tension and wettability of silicon, iron, and nickel in contact with various refractory materials were evaluated at elevated temperatures. Measurements were carried out *in vacuo*, in hydrogen, and in helium. Generally, non-wetting contact angles were observed for iron and nickel with oxides, whereas silicon was found to wet the oxides partially. In all cases the wettability was greater for the metal-graphite and beryllium carbide systems than for the metal-oxide systems. The nature of the atmosphere was found to have a significant effect on the wettability and surface tension of the metal. Wettability results are interpreted on the basis of surface tension and by the consideration of free-energy changes.

Properties of a Tin Oxide-Base Ceramic Body, by John Quirk and C. G. Harman (Battelle Memorial Institute, Columbus, Ohio): Some thermal and mechanical properties were measured for tin oxide-matrix compacts which nominally were composed of 99 per cent. by weight tin oxide (SnO₂) and 1 per cent. zinc oxide (ZnO). The sintered compacts were

similar in strength to high-fire mullite porcelains, had superior resistance to thermal shock, and had high thermal conductivity. The tin oxide body might be expected to give good service under conditions of severe thermal shock and in an oxidising atmosphere at temperatures up to 1500°F.

Energy Relations in Binary Alkali Borates, by L. Shartsis and W. Capps (National Bureau of Standards, Washington, D.C.): The heats of the solution of glasses and devitrified alkali borates in the systems $\text{Li}_2\text{O}-\text{B}_2\text{O}_3$, $\text{Na}_2\text{O}-\text{B}_2\text{O}_3$, and $\text{K}_2\text{O}-\text{B}_2\text{O}_3$ were measured in 2 N nitric acid with a simple vacuum-bottle calorimeter. The standard deviation was 0.35

cal. per gm. for approximately 130 determinations. From these data, together with available thermodynamic data, heats of formation were calculated for alkali borate glasses and devitrified alkali borates from two combinations of possible reactants. All the curves for the heats of solution of glasses showed minima at 20 mole per cent alkali oxide, but similar curves for devitrified alkali borates showed minima at 20 mole per cent, for potassium and sodium borates only. The curve for devitrified lithium borates showed a minimum at 25 mole per cent lithia. The conclusion was drawn that there is probably no congruently melting $\text{Li}_2\text{O} \cdot 4\text{B}_2\text{O}_3$ compound.

POTTERS INSPECT "GRAFTON" KILNS

The Applied Heat Co. Ltd., makers of "Grafton" Electric Pottery Kilns, were at home at Elecfurn Works to a party of potters, amongst them pottery instructors, taking a short course at Pendley Manor, Tring.

A party of more than forty, accompanied by Mr. Murray Fieldhouse of Pendley Manor, spent an afternoon during their course in a tour of those sections of the works dealing with "Grafton" Kilns. A brief visit to the research and development department was followed by demonstrations of element manufacture and welding, brick-making, assembly and testing.

"Pottery Corner," the section equipped with kilns and set aside to provide facilities for those potters who have no firing facilities of their own, was also inspected during the tour, which was followed by a short talk by Mr. W. H. Chapman, the Company's chief designer—himself a potter of no mean ability. The afternoon's visit ended with refresh-

ments during which an opportunity was afforded for any questions arising from what had been seen during the tour.

"JOHNSON" PORTABLE CONVEYOR EQUIPMENT

We have received details of the Loband Loader and improved Hylo-veyor, manufactured by C. H. Johnson (Machinery) Ltd., Stockport, and its use for stockpiling and loading of loose bulk materials.

The equipment eliminates the necessity for tipping on to the ground and then piling with shovel or grab. The machines are highly mobile and are easily manhandled.

The Loband Loader can feed at any angle up to right angles around the Hylo-veyor hopper, and our illustration shows equipment supplied to English Clays, Lovering, Pochin Ltd., St. Austell, Cornwall, and installed at Par Harbour. Here the machines are loading lorry borne china-clay into ships. This clay ranges from dust to 12 in. lumps.



(Photo courtesy Port of Par Authority)

The British Ceramic Society

THE following are abstracts of papers appearing in the January, 1954 issue of the *Transactions of the British Ceramic Society*:

The Quaternary System $\text{CaO-Al}_2\text{O}_3\text{-TiO}_2\text{-SiO}_2$. Pt. II. *The Ternary System Calcium Metasilicate-Sphene-Silica.* Pt. III. *The Quaternary System Calcium Metasilicate-Anorthite-Sphene-Silica.* by Y. M. Agamawi and J. White: The fact that when a silcrete brick in service has picked up lime, its composition will lie in the quaternary volume calcium metasilicate-anorthite-sphene- SiO_2 , led the authors to investigate the thermal-equilibrium diagram of this system. The isoplethal method of study, using the quenching technique, was employed. The equilibrium phases were identified by microscope and x-ray examination.

Part II describes the study of the ternary system calcium metasilicate-sphene- SiO_2 , which had not previously been investigated. This system was found to be of a simple eutectic type, the eutectic occurring at 42.5 per cent. pseudowollastonite; 41.5 per cent. sphene; 16 per cent silica, and 1,320°C.

Part III deals with the investigation of the quaternary system. The primary phase distribution in the ternary section of 30 per cent calcium metasilicate was established. A systematic method for determining the quaternary eutectic point was devised. The latter point was found to occur at 27.5 per cent. calcium metasilicate; 38.3 per cent. anorthite; 9.3 per cent. sphene; 24.9 per cent. SiO_2 , and 1,157±3°C.

Crazing of Wall Tiles. by L. Bullin and K. Green: The paper is divided into three main parts. First the relative importance of moisture-expansion and the "pinch" effect of cement as causes of crazing of wall tiles in service is discussed. Experiments show that moisture-expansion in tiles is still continuing to increase - after steam treatment at 40 lb. per sq. in. for 2,000 hr., and that it is not directly proportional to the body porosity. Either very high temperatures or long periods of drying above 150°C. are necessary to eliminate moisture-expansion from expanded biscuit tiles.

Tests with wall-tiles fixed in sand and cement, and also subjected to other treatments, indicate that the "pinch" effect due to cement contraction on the wall is the primary cause of crazing in service. Moisture-expansion is of only secondary importance when tiles are fixed in this way. Weak cement mixes will

reduce the crazing tendency and the use of mastic adhesives in place of sand and cement eliminate the "pinch" effect altogether.

In the second part the steam autoclave crazing test and the effect on the results of alteration of various conditions in the test are dealt with.

The third part shows that, from a knowledge of the thermal expansion properties of body and glaze and of the moisture-expansion of the body, estimations can be made of the crazing resistance in the autoclave test which agree in general with observed results. Further knowledge of the elasticity of glaze and of body would be necessary to explain the apparent discrepancies.

Cornish Stone: A Method of Quantitative Mineralogical Analysis. by P. S. Keeling: A comparatively rapid method of determining the proportions of the various minerals in Cornish Stone is described. Thin sections of the stone are prepared in the usual way and are stained so that the various minerals can be readily identified under the microscope. A modified mechanical stage enables the slide on which the thin section is mounted to be moved small fixed distances. In effect, the thin section is covered by a fine rectangular grid, the intersections of which are the points underneath the microscope cross-wires at each position of the stage. At each position the mineral underneath the cross-wires is identified and the number of times each mineral occurs is recorded on a counter. In practice, a bank of six counters, five for individual minerals or groups of minerals and the sixth for giving the total, has been found convenient.

LOW-FIRED GLAZES

A review of the likely development of low-temperature glazes and enamels, and a survey of the physical properties of glassy substances was contained in a paper written by Dr. Felix Singer, ceramic consultant, and read by his daughter, Miss Sonia Singer, to a recent meeting of the British Ceramic Society at the North Staffordshire Technical College.

"Development of low-temperature glazes," stated Mr. Singer, "does not require revolutionary changes in glaze composition or manufacture. Study of the structure of glasses and of phase-rule data shows how suitable adjustments can be made to conventional glazes."

Clay Products in South Africa

The Vereeniging Brick and Tile Co. Ltd., Vereeniging, Transvaal, have now provided a special division for the manufacture under licence of the Stalton system pre-stressed burnt clay blocks, which the local building industry is using in floors and lintels. The work is being done in a specially built and equipped factory, and as it has been in operation for some time now it has been possible to supply the trade with the blocks, first for lintels and later for floors. A delay was occasioned in the production of the floor blocks because it was desired to give the product a thorough testing. This being done over a period of time at the factory.

The factory for making these items is initially 50 ft. wide and 260 ft. long and it contains five pre-stressing tables. Most of the machinery has been imported from Switzerland and includes vibrators, a tensioning device and a brick saw. Some of the plant was made in the Vereeniging workshops of the company. It is stated that the initial outlay on the new factory was £25,000. The building trade is now being provided with publicity material on the Stalton system, which is stated to have been used for a long time with notable success in Switzerland, where it originated.

There is said to be a big saving in time and cost by its use, as there is no need for carpenters' shuttering. Large floor areas can be laid by unskilled labour. The pre-stressed units are made in the uniform dimensions of 32 in. by 6 in. In actual use mortar is poured into the grooves in the blocks and also between the small spaces between adjoining blocks and in this way the "pre-stressed" strength is attained. The individual block is light and thus easy to handle. Hollow clay blocks are placed between the beams to complete a hollow block floor without need of shuttering. The system is easy to combine with normal brickwork in cement mortar, providing a reinforced brick beam suitable for the production of lintels.

Suitable deposits for the manufacture of burnt clay bricks, tiles, sanitary pipes, etc., are available in the areas adjacent to the majority of the developed centres of the Union, and stock bricks of varying qualities are produced in many parts.

The production of goods requiring greater mechanisation, such as wire-cut and facing bricks, tiles and sanitary pipes, tends, however, to be concentrated in or near the main consuming centres, and, while the Union as a whole is self-supporting, considerable internal transportation is necessary. According to the Department of Commerce and Industries, burnt clay is finding increasing application in building and much development has taken and is taking place in the production of such commodities as hollow blocks for walling and for reinforced concrete construction. The production of other ceramic building materials such as sanitary ware and wall tiling is in its infancy in the Union. The indications are, however, that suitable deposits of basic raw materials are available in many parts of the Union and that the further development of the industry will depend on the investment of capital and the employment of experienced workers.

Pilkington's Tiles (South Africa) (Pty.) Ltd., Evaton Road, Meyerton, Transvaal, recently added two new shades in glazed coloured tiles for interior wall use, to their manufacturing range. This is No. 1 Sun Tan and No. 1 Ivory. Other new colours and finishes are being added to the range. This company was formed in 1950 and took over a 21-acre site on which is has erected one of the most up-to-date factory buildings in South Africa, equipped with electric kilns. The present factory has a floor area of some 40,000 sq. ft. and has a working staff of some 150.

In the beginning the factory turned out white glazed wall tiles 1 in. thick and 6 in. by 6 in. in size. It was possible to meet about 15 per cent. of the local demand soon after and today about a third of these tiles used in the Union come from this factory. It is making a product comparable to the best similar imported tiles and the prices are claimed to be competitive with those of similar British manufacturers.

Government and municipal authorities in South Africa have been impressed with the quality of this tile and in the past three years have used large quantities on various projects. Much of the clay used in this factory is obtained by the com-

CERAMICS

pany from its own deposits at Koster, in the Transvaal. Kaalfontein, near Pretoria, has been another source of clay, which has also been recovered at Brackenell, in the Cape. It has been possible for this firm to develop a strong export sale of the tiles in the Rhodesias and other African territories and it is hoped to extend this trade considerably in the months to come.

Johnson Tiles (Pty.) Ltd., which is associated with the British firm of H. and R. Johnson Ltd., is a £150,000 company formed to make high-quality glazed wall tiles in a new factory at Olifantsfontein, in the Pretoria district. Much preliminary planning was undertaken before the factory was started. The South African company was started after a pilot plant promised that it could be launched on a profitable basis.

GRANBY PLYSTEEL CARTON

A new Simply-Operated Folding Box

GRANBY METAL PRODUCTS LTD., who have for some time been producing ware trays and boxes, stillages and pallets made from varying gauges of steel framework and plywood panels, have now produced a new simply-operated folding box—known as the Plysteel Carton—at far less cost than their previous collapsible containers.

Basically it follows the design of a normal cardboard fibre carton, the base and the top being identical and closed by the means of the four flaps. It differs however, from the fibre carton inasmuch as it can stand considerable weights being placed on top without any fear of it bowing and thereby damaging the contents, and will last approximately four to five times the number of journeys normally withstood by a fibreboard carton.

These Plysteel Cartons are in effect boxes, since when erected and fastened

or steel strapped, they have the rigidity and strength of a solid box made from the equivalent materials, and yet when folded they take up very little more room than a fibre carton.

The design in question employs plywood panels of any thickness from 3 mm. to 8 mm., all panels and flaps having special thin gauge zinc-plated steel strip riveted to their edges. This strip itself acts as a hinge and allows the box to be folded in exactly the same manner as any fibre carton, whilst at the same time adding to the strength. The base and top inner flaps wedge into the opening and add to the rigidity.

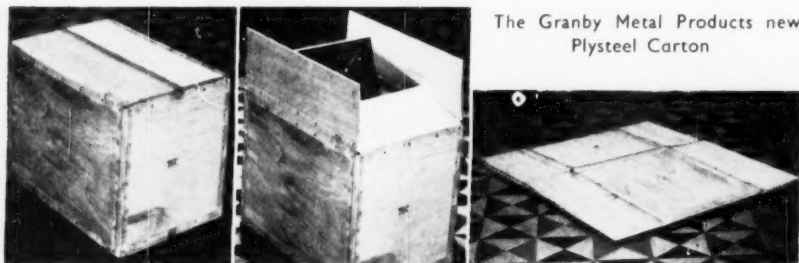
The outer flaps can either be two half-widths meeting in the middle, or one full width, with a second narrow thin flap beneath it. The fastening of these boxes can be achieved in a number of ways—staples, steel or wire tensional strapping, leather straps, toggle clips, or a specially-designed new-type fastener which acts as a seal as well as a fastener. This consists of a special fitting on the inner flap and a hole in the outer flap, and the box is fastened by simply pushing in a rivet with the thumb. Owing to the design of the fixture, the rivet cannot be pulled out unless exceptional force or manipulation is employed.

To open the box, the head of the rivet is cut off with a pair of normal end or inside cutters and the shank of the rivet pushed or pulled out from inside when the box is open.

All containers are made to customers' sizes, but are not recommended for dimensions over 2 ft. 6 in.

The weight of these containers is obviously greater than that of fibre cartons, as indeed is the price, but it is claimed that the cartons will last for a minimum of 20 journeys and have an expected life, under normal conditions, of over 40 journeys. Certainly the special steel strip will bend at least 100 times before breaking, and tests have shown a life of 280 bends.

For a simple, inexpensive and yet strong collapsible box, the Plysteel Carton appears to fill a gap that has existed for some time.



The Granby Metal Products new Plysteel Carton

RETAIL COURSE ON POTTERY

The first pottery course held by the Council of Industrial Design, at Barlaston, last September, proved very successful and was considerably over-subscribed. As a result the Council is following it up with a second course, to be held at the Wedgwood Memorial College, Barlaston, Stoke-on-Trent, from the 1st to 5th March, 1954.

The aim of the course is to give those engaged in buying and selling pottery an opportunity to increase their knowledge of the subject, and discuss the current trends and problems of the pottery trade.

The Lecturers will be:

G. J. V. Bemrose, curator of Stoke-on-Trent Museum and Art Gallery, speaking on "The history of pottery making";

J. E. Hartill, managing director of Minton Ltd., on "Fine china: methods of manufacture";

Alec Heath, M.S.I.A., free-lance designer and consultant, on "Displaying pottery";

Christopher F. Johnson, joint managing director, Johnson Bros. (Hanley) Ltd., on "Earthenware: methods of manufacture";

S. W. Low, buyer and manager of Pottery and Glass, Heal and Son Ltd., on "The retailer's responsibility";

Victor Skellern, art director, Josiah Wedgwood and Sons Ltd., on "Problems of the designer—shape and decoration."

A small exhibition of tableware in current production will be staged at the College and some samples of foreign ceramics will be shown. The programme includes conducted tours of neighbouring pottery factories, where students will

see china and earthenware in all stages of manufacture.

The inclusive charge per head for the course is £8 8s. 0d. Since accommodation is limited, applications should be made as soon as possible to Miss Jean Stewart, Retail Officer, C.o.I.D., Tilbury House, Petty France, S.W.1.

DUMPERS AND LOADERS IN THE CLAY INDUSTRY

From E. Boydell and Co. Ltd., Old Trafford, Manchester 16, manufacturers of Muir-Hill dumpers and loaders, we have received an interesting booklet containing summarised reports on a 4½ cu. yd. dumper, two 3 cu. yd. dumpers and the Company's LH-1 loader in use at Aldridge, Staffs, by Messrs. Aldridge Brick, Tile and Coal Co. Ltd.

Taking as an example the report on the 4½ cu. yd. dumper it is seen it is a standard body machine handling Etruria marl on a 2,240 yd. round trip. The machine runs from the bottom of Utopia quarry up a 1 in 7 gradient to a public road, then to an Arcadia plant hopper. The number of journeys daily is 25 and the weekly tonnage 700 tons. Fuel consumption is 27.75 gallons weekly. The approximate cost of spares each year is given as £75, plus tyres, and the report shows a weekly maintenance time of 5 hours.

This information is typical of that contained in other reports in the booklet, and the Company do say they are pleased to investigate and report upon the suitability of their machines in other undertakings.

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The Italian Ceramic Industry in 1953

TWO separate productions are to be considered in the field of porcelain, namely, pottery ware and products for electrotechnical uses (insulators). For both of them the current year has presented difficult conditions, giving serious causes for worry about the possibility of maintaining a minimum level of employment.

In the field of pottery ware, the market still feels the effect of the importation of considerable quantities of these products from Germany, Japan and the Countries situated beyond the Iron Curtain; these large-scale purchases have been made possible in the first case by the liberal policy adopted by the Italian Government and by the inclusion of important quantities of these articles into the global compensations. The entity of the phenomenon is clearly shown by the statistical data available, which indicate (in comparison with the average values of the pre-war period) a 204 per cent. increment in imports in 1952, and a 292 per cent. increase in the current year. The national industry, which has already lamented a considerable and permanent reduction of work, considers with grave anxiety the near future.

In the production of insulators, a field where the Italian industrialists have largely spent capitals and energies to modernise their plants, the same trend is manifest owing to the almost total discontinuance of the demand on the part of private and public organisations and to the increasing competition of foreign products.

The reduced demand of the national market for pottery ware and insulators is not counterbalanced by the Italian exports which feel the influence of well-known obstacles.

In the field of majolica wall tiles a 10 per cent. productive increment has been observed in 1953 and the labour force is working forty-eight hours a week. The demand of the internal market, limited in the first four months of the present year, has shown a satisfactory development in the successive period.

The sector has, however, felt the effect of the imports from West Germany, England and the Countries situated beyond the Iron Curtain, which have caused a reduction of prices at a moment of particular delicacy and importance to

the national industrialists, financially engaged in the construction of large industrial plants realised in the last years and partly unfinished.

In the sector of ceramic floor tiles the plants have not presented any substantial variation; a limited number of tunnel furnaces and dryers have been built. Only 80 per cent. of the productive capacity of this branch has been exploited in 1953; the employment has been stationary with a slight tendency to diminish owing to the realisation of mechanised and rational cycles of work.

The output has been increased by about 10 per cent. in comparison with the preceding year and has attained the highest level observed till now, thanks to the increased number of factories. The demand of the internal market has followed a rather steady course with a slight reduction in some months, but on the whole has been superior to that of the preceding year, above all in central and meridional regions; prices are stationary.

Owing to well-known reasons of general character, the exports have presented a remarkable contraction, especially if we take into account the fact that the Italian ceramic tiles of the fundamental red colour are sold at a price largely inferior to those adopted by the other European markets. The costs have, however, shown some increase, despite the efficiency of the labour force and the improvement of the plants.

In the field of refractory products several manufacturing concerns have modernised their installations in order to reduce costs, and consequently the productive capacity has been increased in 1953 to 400,000 metric tons, while the effective output has been reduced in comparison with the preceding year and will not exceed, according to the expert's predictions, 180,000 metric tons to 190,000 metric tons. This unfavourable phenomenon is caused by the limited absorption of the national market and by the considerable volume of imports.

Some factories have consequently reduced their activity and a total discontinuance of work is feared in particular cases. The crisis cannot be overcome by increasing the exports, which have on the contrary diminished.

ANNEALING LEHRs

SEVEN new automatically controlled annealing lehrs were installed by a glassworks in the South-east and, to facilitate mechanical handling, a furnace was raised 12 ft. Each lehr is fed through a separate gas meter, and when first installed the lehrs were operated with the manufacturer's burners on compressed air with automatic injector type gas/air mixing. Consumption of gas on this type of burner averaged 260-270 c. ft. per hour for each lehr.

Dissatisfied with the length of flame, the firm conducted experiments with other types of burner, and installed an induced air burner giving a long flame to all lehrs on 100 per cent. gas firing. As a result, gas consumption was reduced to 180 c. ft. per hour.

(Fuel Efficiency News.)

BRICKS FROM BLAST FURNACE SLAG

Colvilles Ltd. have laid down a large commercial brickmaking plant at their Clyde Iron Works to utilise blast furnace slag. Work already done has proved that high quality common building bricks can be produced commercially from this material and the intention is now to expand the initial pilot work on a commercial scale.

Herbert Alexander Ltd. are building the plant which will involve one press in the initial stages; design of the premises is such that four presses can be accommodated in the area. Steam curing using autoclaves is to be adopted and one large autoclave has been constructed to handle the initial output. Here again, the ex-

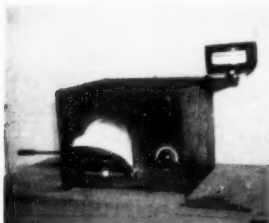
pansion of the plant is visualised by the addition of a second autoclave. This policy will allow processing in eight hours making it possible to produce bricks from raw material to finished article in one day.

The new plant is designed to work on a basis of 97½ per cent. slag to 2½ per cent. lime and productive capacity is rated conservatively at 1,600 per hour.

Sample bricks have been tested by the Building Research authorities and will be put into practical use by the group in its own construction. After this initial period of test and inspection commercial large scale production for general use is intended; in addition to a superior type of common brick it is hoped to produce an attractive facing brick, probably in a range of colours.

The British Ceramic Society.—The Spring Meeting of the Building Materials Section of the Society will be held on the 31st March, 1954, at the Chamber of Commerce, 95 New Street, Birmingham. The morning session will be devoted to the reading and discussion of papers, and in the afternoon members have been invited to visit the Hednesford Brick Works of the National Coal Board, West Midlands Division. An informal dinner is being arranged for the evening of the 30th March.

"600" Announce Fork Lift Hire Fleet.—George Cohen Sons and Co. Ltd., head of the "600" Group, and already operators of a large contractors' plant hire fleet, are now offering Fork Lift Trucks for hire. To all firms faced with occasional handling problems they are offering the latest diesel model L.T.D. "Stacatruc," having a 2-ton, 12-ft. lift.



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Book Review

"The Edward Curran Companies"

Potted histories of the growth of famous companies are nearly always interesting, they often throw an interesting light on the character and personality of the founders and the early leaders who launched them on the way to success. "The Edward Curran Companies" is no exception to this. Privately printed and published to mark the completion of half-a-century of trading, it sets out to tell the story of the growth of the parent company and its associated companies and, on the way, it gives many an idea that could be of use to firms today. Above all it is good reading.

The story starts ninety years ago when the docks of Cardiff were being enlarged and equipped to deal with the output of coal from newly-opened mines of the Rhondda Valleys. It tells how Edward Curran, fourth son of Charles Curran, a stonemason of the period, found an interest in furnace building and started to develop his own system of construction: the "Curran Incandescent Arch" by which he guaranteed a saving of up to 20 per cent. of the coal consumption. To convince the sceptics he and his brother John, had to agree to clauses, in their contracts for construction of their special furnaces, such as the following:

"In the event of the said furnace not meeting with the approval of the Purchasers, the Builders agree to alter them to the present system of working, free of charge."

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In Every Ship of the Royal Navy

A contract for the erection of a range of furnaces at Woolwich Arsenal, led to the firm taking an interest in cartridge case manufacture. This led to the construction of complete factories and equipment during the first world war. After that war the decision was made to embark on the manufacture of enamelled holloware and a special factory was equipped and started up for this project. The story of the development of this factory and the advances and developments in holloware production that came as a result would, alone, make a good book.

Development of activities goes on apace in this half-century record; it describes the establishment of the Oil depot at Cardiff docks by Curran Oils Ltd., the production of foundry specialities by Cardiff Foundry and Engineering Co. Ltd., the work done before and during the last war on re-armament projects, the production of tanks, cartridge cases, machine tools, diesel road rollers for airfield construction, flail devices and Hispano projectiles. It then gives details of the reorganisation which followed the post-war policy of consolidation and the establishment of the group of companies which, six in number, comprise the present-day organisation.

Of these the best known are probably Curran Steels Ltd., who handle the heavy steel castings and machinery side; Edward Curran Engineering Ltd., containing three divisions: holloware, process plant and government contracts division; Curran Oils Ltd., (oil importing, blending and distributing) and Curran Industries Ltd., (electrical, radio and wholesale distributors).

The book runs to over eighty pages, is well produced and illustrated, containing over seventy photographs, drawings and diagrams. Altogether one of the best and most readable "Potted Histories" we have yet seen.

CONTINUOUS ENAMELLING FURNACE

THE initiative and progressive methods of a Stourbridge firm manufacturing enamelled holloware goods have been thoroughly justified by the satisfactory results obtained in increased production, fuel saving and reduced production costs.

In July 1952, two batch-type coal-fired vitreous enamelling furnaces and a Town's gas-fired continuous drying oven were in use, which were considered unsuitable from both practical and economic aspects for the type of load. The coal-fired furnaces have now been superseded by a

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continuous gas-fired enamelling furnace, the waste gases from which pass through a hot gas fan direct to the continuous drying oven, previously fired by Town's gas.

The advantages of the new plant over the in-and-out batch type, together with the maximum use of the furnace waste heat, have reduced total heat requirements by 20 therms/hour. Taking into account the coal equivalent of Town's gas used, there is a direct coal saving of 55 per cent., and, in addition, the output of the plant shows a 50 per cent. increase over the previous production capacity. The full cost of production has been reduced by 30 per cent.

(*Fuel Efficiency News.*)

INSTITUTE OF CLAY TECHNOLOGY

Speaking at the recent annual dinner of the North Staffordshire Branch of the Institute of Clay Technology, Mr. J. W. Wright (president), said the Institute was the only national body attached to the clay industry which, by means of its branches, enabled people in different parts of the country to attend meetings and to gain some knowledge of the industry which they served. At the present time, said Mr. Wright, the Institute was in the healthiest position it had ever attained. They had over 600 members and nine branches. It was a record of which they could be proud, but it was not enough; he would like to see 600 really active members. Then they would be able to spread aims and ideals of the institute to every area where there was a clay-working centre, and the Institute could become a truly national body.

Proposing a toast to the North Staffordshire Branch, Mr. A. A. Thompson (Institute chairman) said the Branch was fortunate in having so many leading men in the industry as members. He paid tribute for the help the Branch had received from the North Staffordshire Technical College and the British Ceramic Research Association.

RIGHT GOODS AT RIGHT PRICE

Responding to the toast of "The Visitors" at the recent annual staff and works council dinner of Wood and Sons Ltd., Burslem, Mr. W. F. Wentworth-Shields, director of the British Pottery Manufacturers' Federation, said there were two main questions facing Britain's pottery industry: How do we rank overseas? and, How hard do we need to work to keep the present position? Both questions, he thought, depended entirely on the amount of effort manufacturers were willing to put into the job.

Mr. H. Francis Wood (managing director), who proposed the toast said that if we are going to hold our own, there is no doubt that we must continue to give first-class quality. We are now up against the question of prices, and if we are going to survive as an exporting industry, we must "provide the right goods at the right prices."

A toast to the firm was proposed by Mr. W. H. Whieldon, and in reply Mr. Harry F. Wood (chairman), who has been with the firm for more than 64 years, said he had always appreciated the spirit of team work which existed among employees.

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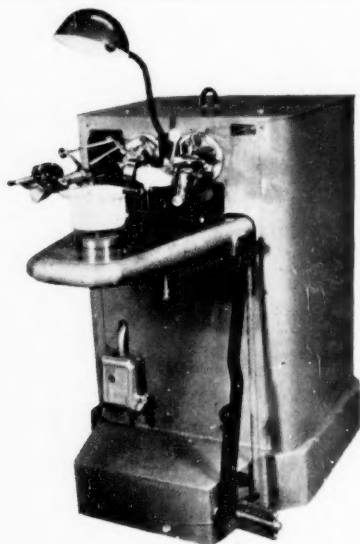
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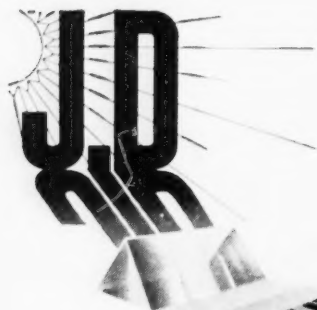


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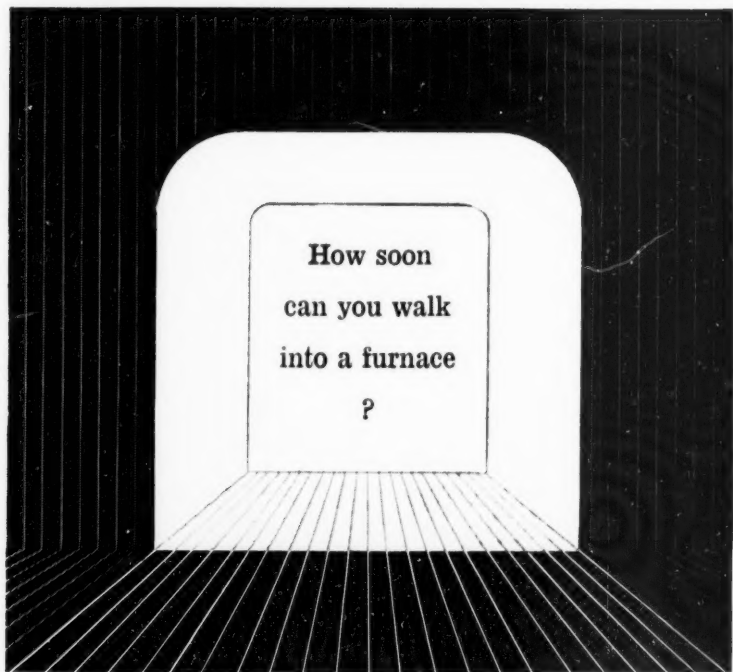
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